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DISCOVERY

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UofA
DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

UNIVERSITY OF ARKANSAS
DALE BUMPERS COLLEGE
OF AGRICULTURAL, FOOD
& LIFE SCIENCES

DISCOVERY

The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

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UNIVERSITY OF ARKANSAS DALE BUMPERS COLLEGE OF AGRICULTURAL, FOOD & LIFE SCIENCES

Cover: Aki Kogo works with her faculty mentor, Thad Scott, on research for her honor's thesis project, Short-Term Denitrification in the Metalimnion of a Eutrophic Reservoir. Photo by Fred Miller.

Letter from the Dean

Michael Vayda

Enhanced-Learning Experience

The Bumpers College of Agricultural, Food and Life Sciences is committed and dedicated to preparing our students to become leaders for the economic and social well-being of Arkansas, the region, nation and beyond by producing graduates for careers that matter—in the areas of food, family and the environment.

We are proud of the quality of our students and the work they do. The *DISCOVERY* undergraduate journal gives us an opportunity to highlight the exceptional work of just a few of our students as they report on the results of research projects conducted in partnership with faculty mentors.

The journal is an enhanced-learning experience as it encourages our students to engage beyond the classroom, offers an outlet to share results and findings in a citable publication, and provides a service to society.

We encourage student research by awarding undergraduate research grants. Our students have been competitive for research and travel grants awarded by the Honors College and the Arkansas Department of Higher Education, and many projects are designed to meet the requirements for an honors thesis in the Bumpers College Honors Program.

We are pleased to present this issue to you as an example of the exceptional work of our undergraduates. Congratulations to the student authors, and thank you to the faculty mentors and editors who contributed to their projects.

Michael Vayda, Dean and
Associate Vice President–Academic Programs

Undergraduate Research Articles

Influence of organic groundcovers on mycorrhizal colonization and symbiosis of organically managed fruit crops

Raven Anai Bough and Curt R. Rom*[†]

ABSTRACT

Ground covers have the potential to impact the crop rhizosphere biology, which includes organisms such as arbuscular mycorrhizal fungi (AMF), which in turn affect the crop host plant through symbiosis. There has been evidence that a ground cover that provides a suitable environment for colonization of AMF and subsequent symbiosis could be a tool in organic fruit production. The objective of this research was to compare colonization of AMF in strawberry plant (*Frageria x ananassa* cv. Radiance) and apple rootstocks (*Malus x domestica*, cv. M. 26) grown in a greenhouse affected by various ground cover treatments. Inoculation was achieved by mixing BioOrganics™ Endomycorrhizal Inoculant directly into soilless media according to label rates. Following a dormancy period, plants were treated with one of the following ground cover treatments: 1) city-generated urban green-compost (GC), 2) shredded white paper, 3) urban refuse wood chips or 4) an untreated control. The GC ground cover significantly increased percent colonization of AMF compared to other ground covers; however, AMF infection did not affect plant biomass, root volume, root surface area, root diameter, or leaf area. The AMF suppressed root length; plants inoculated with AMF had shorter roots but similar root volume to compared to non-inoculated plants. The GC treatment may have disproportionately contributed more nutrition by media composition of a smaller particle size and a decreased lignin, cellulose, and hemicellulose content compared to other ground cover treatments. Though the ground covers in this study had no effect on symbiotic AMF benefits, long-term studies with mature host plants could reveal a correlation between ground cover media and symbiosis.

* Raven Bough is a May 2013 Honors graduate with a major in Horticulture and a minor in Biology.

† Curt Rom is the faculty mentor and is the Director of the Dale Bumpers College of Agricultural, Food and Life Sciences Honors Program and a professor in the Department of Horticulture.

MEET THE STUDENT-AUTHOR

Raven Anai Bough

I am a proud native of Fayetteville, Arkansas and graduated from Fayetteville High School in 2009. The following fall semester, I began studying Horticulture at the University of Arkansas. To gain supplemental skills and experience necessary for a career in research, I also pursued a minor in biology, worked as a lab-assistant for the Department of Horticulture, worked at a local plant nursery and retail center, and completed an internship funded by the National Science Foundation Research Experience for Undergraduates at the non-profit Donald Danforth Plant Science Center. Another research project I conducted in addition to the following study was a team effort entitled "Herbicide-Resistant Soybeans in Arkansas: Lessons Learned and Future Direction," where I focused on crop science issues and implications.

I plan to attend graduate school in California, the heart of United States fruit production, to pursue a career in horticultural plant breeding for crop improvement. Ultimately, I hope to attain a Ph.D. and manage my own laboratory and research programs in either a university or industry setting.

INTRODUCTION

In the past decade, both the total market value of organic fresh fruits and vegetables and the extent of organic cropland have nearly tripled (Greene, 2012). Public concern over chemical nonpoint source pollution from agriculture runoff, the leading cause of negative water quality impacts (EPA, 2012), has been a factor in rising consumer demand for organic products. The USDA Certified organic weed management programs must utilize non-synthetic chemical herbicide weed control methods due to strict regulations created by the National Organic Program (CPWDMPS, 2013).

Organic ground covers are a useful tool in organic production to physically suppress weeds with minimal or no additional herbicide input. Other advantages include erosion protection, increased water infiltration and availability, soil temperature regulation, and supplemental nutrition through the decomposition of organic matter (Pinamonti, 1998). Organic ground covers have the potential to alter the rhizosphere of a crop, including arbuscular mycorrhizal fungi (AMF), because of direct contact with the soil and decomposition over time. The AMF form a symbiotic relationship with a host plant in which fungi receive plant-produced carbohydrates and host plants are provided with increased nutrient and water uptake, environmental stress resistance (Sylvia and Williams, 1992), and pathogen resistance (Linderman, 2000). The AMF are found in association with roots of various fruit crops, including commercial strawberries (*Fragaria x ananassa* Duchense) and apple (*Malus x domestica* Borkh.)(Smith and Read, 1997).

Numerous studies have also shown the ability of AMF colonization to increase root, shoot, and fruit growth in both annual and perennial fruit crops. Yet, research is limited on the impact of organic ground covers on AMF symbiosis and its effects. Colonization by AMF has been found to be highest in soils with organic matter versus pure sand (Sylvia and Williams, 1992) and in strawberry and apple roots where peat and bark served as ground cover media compared to manure or sawdust (Derkowska et al., 2008). The objective of this research was to determine the influence of organic ground cover treatments on AMF colonization and symbiosis in terms of strawberry plant and apple tree growth. This project was part of a larger project on Best Management Practices for Organic Apple Orchards (NIFA-OREI 406).

MATERIALS AND METHODS

In January 2012, single strawberry plant propagation plugs (cv. Radiance) were transplanted into 20 cm × 18 cm plastic pots with chemically inert clay media. At planting, plants were given one of three treatments: 1) a control (NI) for inoculant treatment, 2) inoculated BioOrganics™ Endomycorrhizal Inoculant (BEI), or 3)

MegaGro® MycoBoost (MB), both applied at recommended label rates. After planting, plants were given one of the following four treatment combinations: A) a control (CK), B) city-generated green compost (GC), C) shredded paper (SP), or D) wood chips (WC) for a total of 12 treatments in the 3 × 4 factorial design. The experiment evaluated 10 replications of individual plant experimental units. Plants were arranged in a randomized design and grown in a greenhouse for 12 weeks after ground cover media application. Plants were watered by hand as necessary and each was provided with an application of 1.25 L (1:500 v/v fertilizer:water) of Scott's Miracle-Gro® Water Soluble All-Purpose Fertilizer at six weeks. Plants had access to full sun throughout the day. Ambient greenhouse temperatures were maintained between 20-25 °C for daytime hours and 25 °C for nighttime hours.

For a second study, in April 2012, rooted apple rootstocks (M. 26) were transplanted into 25 cm × 23 cm plastic pots with media of equal amounts of sand, vermiculite, and perlite by volume. As buds emerged, each plant was limited to one shoot by pinching to remove other laterals. Experimental treatments, experimental design, and duration were identical to that of the previously described strawberry experiment. Plants were watered by hand as necessary and each provided with an application of 1.75 L (1:500 v/v fertilizer:water) of Scott's Miracle-Gro® Water Soluble All-Purpose Fertilizer at 6 weeks. Plants had access to full sun throughout the day. Ambient greenhouse temperatures were maintained between 25 - 35°C for daytime hours and 25°C for nighttime hours.

Arbuscular Mycorrhizal Fungi Quantification. Root samples were cleared and stained according to a procedure by Sylvia (1994). The clearing agent was 1.8 M KOH and the bleaching agent was 30% wt/wt hydrogen peroxide acidified with a few drops of 5 M HCl. The stain was composed of 800 mL glycerine, 800 mL lactic acid, 800 mL distilled water, and 1.2 grams of trypan blue. Roots were stored in cold water after staining until processing. The grid-line-intersect method was used to determine percent AMF colonization with an average of 100 intersections per sample (Clapp et al., 1996).

Root and Vegetative Analysis. Roots were washed to clean them from soil particle matter. Roots were analyzed for length, average diameter, surface area, and volume using the WinRHIZO© scanner and software (Regent Instruments, Inc., Quebec, Canada). Root surface-area-to-volume ratio was calculated from these data. After measurements, half of the 10 replicates were randomly selected for AMF infection quantification. A 0.25-g sample of fresh roots was removed and stored in a tissue cassette in cold water until processing. The remaining roots were dried for 48 hours at 35-40 °C to measure root biomass.

Plants were harvested for growth assessments after 12 weeks of treatments. For both strawberry and apple plants, leaf area was measured with an area meter using a LiCor® Li-3000A portable area meter (LiCor Biosciences, Lincoln, Neb.). Total area was measured and average leaf area and specific leaf weight was calculated. Final shoot length of new shoot growth was measured for apple rootstocks. Apple and strawberry leaves as well as strawberry crowns were dried for 48 hours at 35-40 °C to measure vegetative biomass.

Statistical Analysis. The NI treatments and BEI treatments were selected to represent negative and positive AMF colonization, respectively. The treatment effects of inoculant × ground cover, inoculant, and ground cover were assessed. Statistical analysis was conducted using StatPlus (AnalystSoft Inc., Vancouver, B.C., Canada). Significance of differences were evaluated using two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) where $P = 0.05$.

RESULTS AND DISCUSSION

Strawberry. In the strawberry study, the GC ground cover had a positive effect of increasing AMF root colonization in BEI inoculated treatments (Table 1). The BEI treatment resulted in overall larger colonization for each ground cover, though the CK and SP ground covers increased colonization in NI inoculated treatments.

The interaction between colonization treatment and ground cover treatment was only found to have significant differences in growth for total root length, average root diameter, and leaf area for strawberry (Table 1). Total root length was largest with ground cover treatments CK and GC in the NI inoculant treatment, with only GC in the NI inoculant treatment resulting in a mean different than that of GC in the BEI inoculant treatment. Average root diameter was significantly larger for CK, GC, and SP ground cover treatments in the BEI inoculant treatment than the NI inoculant treatment, with GC exhibiting the largest value. Leaf area was largest with the ground cover treatment GC in the NI inoculation treatment, which was significantly different compared to the BEI inoculation treatment.

Though past studies have demonstrated beneficial AMF symbiotic effects in terms of increased vegetative and root growth, this study showed minimal growth benefits due to AMF colonization. Variables that did not differ between inoculation treatment means for total ground cover treatments were leaf area (Table 1) and root dry weight, root surface area, root volume, aerial dry weight components, and total aerial dry weight (Table 2). Total root length and average root diameter varied significantly among ground cover treatments (Table 1), as did root-surface-area-to-volume ratio (Table 2). The AMF appeared to increase average root diameter yet suppress total root length and root-surface-area-to-volume ratio. Root surface-area-to-volume ratio, which at larger values indicates increased root exposure to the environment for increased water and nutrient absorption (Bucher, 2004; Nijhoff, 1983), is typically increased in a host plant by AMF symbiosis (Bucher, 2004). This study contradicts this idea in strawberry plants.

Total ground cover treatments of NI + BEI resulted in significant differences among ground cover effects for plant growth (Tables 1 and 2). Average root diameter, root dry weight, root surface area, root volume, aerial dry weight components, leaf area and total aerial dry weight were largest for GC and insignificantly different between CK, SP, and WC. Root surface-area-to-volume-ratio was largest but not different between CK, SP, and WC, and was smallest for GC. Colonization of AMF was largest but not different between CK, GC, and SP, and was smallest for WC. Total root length was largest for CK and GC, followed by SP and WC.

Apple. In the apple study, the BEI inoculation treatment resulted in overall larger colonization for each ground cover than the NI inoculation treatment (Table 3). The GC ground cover treatment had a positive effect of increasing AMF root colonization in BEI inoculated treatments more than SP or WC. The CK treatment had the smallest colonization among ground covers inoculated with BEI, demonstrating the effectiveness of a ground cover to boost colonization in apple plants.

As found in the strawberry study, the interaction between colonization treatment and ground cover treatment in apple plants was only found to have significant differences in growth for total root length (Table 3). Total root length was largest with GC in the NI inoculant treatment which was significantly largest than the total root length mean with GC in the BEI inoculant treatment.

As with the strawberry study, in this study treatments resulted in minimal growth differences due to AMF colonization. Variables that did not differ among inoculation treatment means for total ground cover treatments were root dry weight, root diameter, root surface area, root volume, leaf area, shoot length, aerial dry weight components, and total aerial dry weight (Table 4). Total Root length (Table 3 and root surface-area-to-volume ratio (Table 4) varied among inoculation treatments with the varying ground covers. The AMF appeared to suppress total root length and root-surface-area-to-volume ratio in apple plants in addition to strawberry plants.

Total ground cover treatments of NI + BEI resulted in significant differences between ground cover effects on growth (Tables 3 and 4). Total root length, root dry weight, root diameter, root surface area, root volume, leaf area, shoot length, aerial dry weight components, and total aerial dry weight means were largest for GC and insignificantly different between CK, SP, and WC for total root length, root surface area, root volume, aerial dry weight components, and total aerial dry weight. The CK and WC treatments resulted in significantly smaller root dry weight and root diameter than either GC or SP. Shredded paper appeared to have a detrimental effect on both leaf area and shoot length compared to the other ground covers due to smaller means, though WC had a similar mean for leaf area. Root surface-area-to-volume-ratio was largest for CK and WC, followed by SP, and GC. Colonization of AMF was largest for GC, followed by SP and WC, and CK with the least value.

CONCLUSIONS

Though supplemental fertilizer was provided, ground cover treatments may have contributed disproportionately to plant and AMF nutrition. In green composting processes, it is common practice to grind, chip, or shred materials into smaller particles, which increases the surface area available for nutrient absorption (EPA, 2013). Plants may have been able to readily assimilate a proportion of the organic matter in GC. The WC, however, generally consists of large pieces of material that have less surface area available for nutrient absorption and contain lignin, cellulose and hemicellulose, which are difficult for microorganisms and plants to break down for nutrient release (Pan et al., 2005). The SP has a similar composition to WC and is also difficult to break down (Biermann, 1993). The GC provided more readily available nutrients compared to SP or WC, resulting in the greatest plant growth (shoot length, leaf area, aerial and root dry biomass, root volume) at similar rates in NI or BEI treatments. As previously mentioned, GC had a positive effect on AMF in inoculated plants by increasing colonization, indicating AMF need of available organic matter for establishment, which supports past data (Sylvia and Williams, 1992).

This study demonstrated the potential of GC as a ground cover for increasing AMF colonization compared to SP and WC, most likely due to increased available organic matter. Despite greater percent AMF infection in inoculated plants in the presence of GC, beneficial symbiotic effects of increased leaf area, shoot length for apple, root volume, root length, root surface area, or root volume-to-surface-area ratio were not demonstrated in this short-term study with strawberry and apple. In fact, GC application overrode any effect of AMF on plant growth. However, measurements were not conducted for increased water efficiency, pathogen suppression, or foliar P content. These potential beneficial effects would be useful in organic fruit production, and could be affected by various ground cover media treatments. It would be valuable for future studies to examine these variables.

Another limitation of this study was duration. Future long-term greenhouse studies would be useful to determine the effect of ground cover media on AMF beneficial symbiosis for mature fruit crops. Long-term field studies would further provide real world analysis of the relationship of ground covers on AMF colonization and symbiosis.

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We would like to acknowledge the financial support provided by the University of Arkansas Honors College for this project. This project would not have been possible without proposal support from Duane Wolf, and technical support from Jason McAfee. We would also like to thank Joey Young for assisting in the WinRHIZO root analysis. This project was labor intensive at times, and we appreciate the assistance provided by undergraduate horticulture colleagues, Spencer Fischer, Tyler Patrick, and Jay Gates, as well as Raven Bough's partner, Aidan Lancaster, and friend, Cameron Jordan.

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Table 1. Effect of inoculation treatment, ground cover treatment, and their interaction on arbuscular mycorrhizal fungi (AMF) root colonization, total root length, average root diameter, and leaf area of strawberry plants.

Treatment		AMF Colonization (%)	Total Root Length (cm)	Average Root Diameter (cm)	Leaf Area (cm^2)
Inoculant	**Ground Cover**				
Control	Control	24.93 ± 2.00 a‡	3284.00 ± 668.49 a	0.44 ± 0.08 ns	122.11 ± 38.11 b
	Green Compost	13.01 ± 3.15 b	3534.63 ± 498.65 a*	0.51 ± 0.08 ns	215.60 ± 30.62 a*
	Shredded Paper	21.97 ± 3.67 a	2669.91 ± 478.35 b	0.46 ± 0.06 ns	90.55 ± 44.77 b
	Wood Chips	11.22 ± 3.42 b	2477.59 ± 829.02 b	0.50 ± 0.09 ns	114.30 ± 76.56 b
	Total	17.78 ± 6.61 B§	2991.53 ± 750.82 A	0.48 ± 0.08 B	135.64 ± 68.49 NS
BEI†	Control	35.77 ± 3.28 b*	2619.90 ± 332.38 ns	0.54 ± 0.08 bc*	122.18 ± 28.95 ns
	Green Compost	51.15 ± 3.24 a*	2690.37 ± 455.00 ns	0.66 ± 0.13 a*	131.38 ± 93.11 ns
	Shredded Paper	41.36 ± 3.62 b*	2684.37 ± 373.30 ns	0.55 ± 0.08 b*	112.45 ± 27.05 ns
	Wood Chips	40.36 ± 2.95 b*	2505.57 ± 416.13 ns	0.49 ± 0.07 c	108.65 ± 40.09 ns
	Total	42.16 ± 6.49 A	2625.05 ± 388.65 B	0.56 ± 0.11 A	118.67 ± 53.05 NS
Control + BEI	Control	30.35 ± 6.26 α¶	2951.95 ± 616.50 αβ	0.49 ± 0.09 β	122.14 ± 32.94 β
	Green Compost	32.08 ± 20.33 α	3112.50 ± 635.15 α	0.59 ± 0.13 α	173.49 ± 80.11 α
	Shredded Paper	31.67 ± 10.78 α	2677.14 ± 417.67 βγ	0.51 ± 0.08 β	101.50 ± 37.71 β
	Wood Chips	25.79 ± 15.65 β	2491.58 ± 638.58 γ	0.50 ± 0.08 β	111.48 ± 59.55 β

† BioOrganics Endomycorrhizal Inoculant.
‡ Lowercase letters represent differences between ground cover treatments within an inoculant treatment where means labeled with the same letter are not significantly different according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, n = 10). No statistical significance is noted by ns.
§ Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 40). No statistical significance is noted by NS.
¶ Lowercase Greek letters (greatest to least mean: α, β, γ) represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 20).
* Represents statistically significant differences between the same ground cover treatments in both inoculation treatments according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 10). The largest mean is noted.

Table 2. Effect of ground cover treatment and inoculation treatment on (a) root dry weight, root surface area, root volume, root surface-area-to-volume ratio, and (b) aerial dry weight components and total aerial dry weight of strawberry plants.[†]

a.

Treatment: Inoculant	Treatment: Ground Cover	Root Dry Weight (g)	Root Surface Area (cm^2)	Root Volume (cm^3)	Root Surface-Area-to-Volume Ratio (cm^{-1})
Control	Total	0.81 ± 0.36 NS[§]	455.91 ± 151.88 NS	5.69 ± 2.71 NS	85.96 ± 14.78 A
BEI[‡]	Total	0.91 ± 0.39 NS	464.33 ± 121.75 NS	6.77 ± 3.05 NS	73.89 ± 13.29 B
Control + BEI	Control	0.78 ± 0.32 b[¶]	449.37 ± 101.75 b	5.64 ± 2.09 b	84.59 ± 16.82 a
	Green Compost	1.13 ± 0.41 a	563.66 ± 125.13 a	8.49 ± 3.30 a	71.27 ± 15.26 b
	Shredded Paper	0.83 ± 0.33 b	428.71 ± 110.27 b	5.59 ± 2.24 b	81.09 ± 12.77 a
	Wood Chips	0.69 ± 0.31 b	398.74 ± 152.55 b	5.20 ± 2.78 b	82.75 ± 13.18 a

b.

Treatment: Inoculant	Treatment: Ground Cover	Crown Dry Weight (g)	Petiole Dry Weight (g)	Leaf Dry Weight (g)	Total Aerial Dry Weight (g)
Control	Total	4.00 ± 1635 NS	0.57 ± 0.43 NS	3.77 ± 2.03 NS	8.35 ± 3.81 NS
BEI	Total	4.15 ± 1.35 NS	0.58 ± 0.52 NS	3.78 ± 2.25 NS	8.51 ± 3.88 NS
Control + BEI	Control	3.61 ± 1.00 b	0.37 ± 0.21 b	3.27 ± 0.88 b	7.25 ± 1.87 b
	Green Compost	5.23 ± 1.69 a	1.19 ± 0.50 a	6.16 ± 2.45 a	12.59 ± 4.18 a
	Shredded Paper	3.78 ± 1.46 b	0.34 ± 0.24 b	2.73 ± 1.03 b	6.84 ± 2.60 b
	Wood Chips	3.67 ± 1.14 b	0.41 ± 0.23 b	2.94 ± 1.70 b	7.03 ± 2.92 b

[†] The differences in interactions between inoculation and ground cover treatments were not found to be statistically significant according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, n = 10) and these means are therefore not listed.

[‡] BioOrganics Endomycorrhizal Inoculant.

[§] Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 40). No statistical significance is noted by NS.

[¶] Lowercase letters represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 20).

Table 3. Effect of inoculation treatment, ground cover treatment, and their interaction on percent (%) arbuscular mycorrhizal fungi root colonization and total root length of apple plants.

Treatment		AMF Colonization	Total Root Length
Inoculant	Ground Cover	(%)	(cm)
Control	Control	4.34 ± 0.90 ns‡	1297.23 ± 469.32 bc*
	Green Compost	4.91 ± 2.00 ns	2169.94 ± 404.14 a*
	Shredded Paper	4.03 ± 1.20 ns	1030.67 ± 313.07 cd
	Wood Chips	4.65 ± 0.70 ns	797.26 ± 348.30 d
	Total	4.48 ± 1.24 B§	1323.78 ± 644.99 A
BEI†	Control	33.99 ± 4.74 c*	879.90 ± 388.82 b
	Green Compost	53.37 ± 2.29 a*	1508.81 ± 585.76 a
	Shredded Paper	41.17 ± 4.32 b*	1059.04 ± 365.02 ab
	Wood Chips	44.94 ± 3.18 b*	993.09 ± 353.32 b
	Total	43.37 ± 7.95 A	1110.21 ± 481.82 B
Control + BEI	Control	19.17 ± 15.96 γ¶	1088.57 ± 470.93 β
	Green Compost	29.14 ± 25.62 α	1839.37 ± 595.75 α
	Shredded Paper	22.60 ± 19.80 β	1044.85 ± 331.29 β
	Wood Chips	24.80 ± 21.34 β	895.18 ± 355.93 β

† BioOrganics Endomycorrhizal Inoculant.

‡ Lower case letters represent differences between ground cover treatments within an inoculant treatment where means labeled with the same letter are not significantly different according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, n = 10). No statistical significance is noted by ns.

§ Capital letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 40).

¶ Lower case Greek letters (greatest to least mean: α, β, γ) represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 20).

* Represents statistically significant differences between the same ground cover treatments in both inoculation treatments according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 10). The largest mean is noted.

Table 4. Effect of ground cover treatment and inoculation treatment on (a) root dry weight, average root diameter, root surface area, root volume, root surface-area-to-volume ratio, and (b) leaf area, shoot length, aerial dry weight components, and total aerial dry weight of apple plants.†

a.

Treatment: Inoculant	Treatment: Ground Cover	Root Dry Weight (g)	Root Diameter (cm)	Root Surface Area (cm²)	Root Volume (cm^3)	Root Surface-Area-to-Volume Ratio (cm^{-1})
Control	Total	1.01 ± 0.85 NS§	0.67 ± 0.22 NS	302.50 ± 207.70 NS	6.05 ± 6.31 NS	63.99 ± 16.11 A
BEI‡	Total	1.13 ± 1.02 NS	0.75 ± 0.33 NS	297.95 ± 220.03 NS	6.66 ± 6.94 NS	54.33 ± 20.21 B
Control + BEI	Control	0.52 ± 0.36 c¶	0.55 ± 0.18 c	197.33 ± 99.09 b	2.99 ± 2.01 b	69.00 ± 21.03 a
	Green Compost	2.24 ± 0.88 a	0.97 ± 0.38 a	576.86 ± 204.38 a	14.50 ± 7.65 a	41.15 ± 13.62 c
	Shredded Paper	0.96 ± 0.73 b	0.74 ± 0.19 b	253.67 ± 134.50 b	5.21 ± 4.29 b	57.33 ± 13.33 b
	Wood Chips	0.56 ± 0.37 c	0.59 ± 0.09 bc	173.05 ± 85.19 b	2.72 ± 1.64 b	69.15 ± 10.61 a

b.

Treatment: Inoculant	Treatment: Ground Cover	Leaf Area (cm^2)	Shoot Length (cm)	Shoot Dry Weight (g)	Leaf Dry Weight (g)	Total Aerial Dry Weight (g)
Control	Total	723.93 ± 743.28 NS	40.61 ± 23.79 NS	3.70 ± 4.14 NS	5.43 ± 5.33 NS	9.13 ± 9.26 NS
BEI	Total	723.17 ± 741.54 NS	38.84 ± 24.16 NS	3.72 ± 4.77 NS	5.97 ± 6.55 NS	9.69 ± 11.28 NS
Control + BEI	Control	524.53 ± 237.95 b	34.28 ± 11.60 b	1.93 ± 0.96 b	3.87 ± 1.71 b	5.79 ± 2.64 b
	Green Compost	1708.98 ± 871.98 a	72.30 ± 21.60 a	10.35 ± 4.24 a	13.83 ± 6.82 a	24.18 ± 10.70 a
	Shredded Paper	218.74 ± 97.92 c	20.78 ± 7.17 c	1.00 ± 0.58 b	1.79 ± 0.73 b	2.79 ± 1.21 b
	Wood Chips	441.95 ± 143. 45 bc	31.55 ± 10.70 b	1.58 ± 0.81 b	3.29 ± 1.13 b	4.87 ± 1.86 b

† The differences in interactions between inoculation and ground cover treatments were not found to be statistically significant according to two-way analysis of variance (ANOVA) and Fisher's least significant difference (LSD) ($\alpha < 0.05$, n = 10) and these means are therefore not listed.

‡ BioOrganics Endomycorrhizal Inoculant.

§ Capitol letters represent differences between inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 40). No statistical significance is noted by NS.

¶ Lower case letters represent differences between ground cover treatments across both inoculant treatments where means labeled with the same letter are not significantly different according to two-way ANOVA and Fisher's LSD ($\alpha < 0.05$, n = 20).

The influence of poultry litter biochar on early season cotton growth

Taylor D. Coomer, David E. Longer†, Derrick M. Oosterhuis§, and Dimitra A. Loka‡*

ABSTRACT

Cotton is known for being sensitive to cool, wet soils, especially in the early stages of growth. Amendments to soil can aid cotton seedlings in development and nutrient uptake. However, soil amendments can be costly and detrimental to the environment, and alternatives such as the addition of biochar have been considered. Biochar is produced from biomass that has gone through pyrolysis and has been shown to improve plant yield, microbial response, soil structure, soil cation–exchange capacity, and water use efficiency. This study was conducted to evaluate the effect of biochar on early season cotton growth. The aim of this study was to determine whether biochar aids nutrient uptake and seedling development during the seedling's life cycle. The study was established in October 2013 in the greenhouse at the University of Arkansas using a randomized complete block design with three replications. Treatments included a control with no fertilizer or biochar, a control with fertilizer (56 kg N/ ha) and no biochar, and two fertilizer treatments (0 or 56 kg N/ ha) each with 1500 or 3000 kg/ha biochar. Plants were grown for eight weeks then harvested to collect plant height, plant fresh weight, plant dry weight, and leaf area. Data showed that the highest level of biochar with additional fertilizer provided the best growth response in plant height, fresh weight dry weight, and leaf area at 27.52 cm, 14.7g, 1.87 g, and 419.48 cm^2, respectively.

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MEET THE STUDENT-AUTHOR

Taylor D. Coomer

I grew up on a family cotton farm in Piggott, Arkansas, where I graduated from Piggott High School. I came to the University of Arkansas as a pre-med student, but decided to pursue a career in the field I knew from childhood. I am a senior Environmental, Soil, and Water Sciences student and am particularly interested in soil science and plant nutrition. I will begin my M.S. with Dr. Oosterhuis in the spring of 2014 studying potassium in cotton. I am involved with the University of Arkansas Crop, Soil, and Environmental Sciences Club on campus, and I am also involved with various volunteer groups in the community. In my spare time I enjoy running, teaching kickboxing and yoga classes, fishing, and hiking.

INTRODUCTION

Over time, soil fertility declines due to plants' harvesting of the soil's valuable resources for the production of grain and residue. Replacing soil nutrients yearly does put them back into the soil, but over time, the soil may become less fertile, and its cation-exchange capacity will decline, reducing the soil's ability to hold nutrients (Laird et al., 2010a). Soils also experience decline in water holding capacity (Kammann et al., 2010) and pH levels (Uzoma et al., 2011). Yearly soil amendments such as manures can be added to the soil to preserve fertility, and while helpful, they are expensive and time consuming to apply (Uzoma et al., 2011). Other alternatives have been explored to replace these additives. One viable option is the addition of biochar.

Biochar (BC) is produced from biomass that has gone through pyrolysis. Pyrolysis is the process of heating in the absence of oxygen (Chan et al., 2008). Biochar is composed of mostly decomposition-resistant polyaromatic carbon. Scientists estimate that BC can resist total decomposition for hundreds to thousands of years (Doydora et al., 2011). Biochar can be produced from virtually any biomass including plant wastes like peanut hulls (Kammann et al., 2010), coffee husks (Dias et al., 2009), animal wastes (Uzoma et al., 2011; Chan et al., 2008), industrial wastes (Van Zwieten et al., 2009), and woody materials (Laird et al., 2010b). Some data show that BC from plants is not as nutrient-rich or as effective compared to BC from animal wastes because of low nitrogen levels (Chan et al., 2008) in plants that do not already have high nitrogen content, such as legumes.

In recent times, studies have been completed to determine what BC can do for the soil, plant, and water ecosystem and what processes BC affects the most. Generally, BC keeps soil fertility high and may increase sequestration of carbon in the soil (Chan et al., 2008). Biochar can support retention of nutrients and other organic material in the soil because of its porosity, high surface area, and areas of both polarization and no polarization (Laird et al., 2010a). Adding BC to a sandy soil can improve soil moisture content and soil cation-exchange capacity because of its high surface area and large charge density (Uzoma et al., 2011).

Biochar addition to soil has increased both plant growth and yield especially when nitrogen-based fertilizer is added (Kammann et al., 2010). One study conducted with peanut hull BC and quinoa (*Chenopodium quinoa* Willd) cultivated in a poor sandy soil showed that grain yield and water use efficiency were both increased with the addition of BC. The highest water use efficiency was at the intermediate BC application rate of 100,088.84 kg/ha (100 metric t/ha) with reduced water, showing that there is a point at which BC application can be too high (Kammann et al., 2010).

Poultry litter BC is of special interest because of the incredible amount of litter produced by poultry houses in the United States, and especially in northwest Arkansas. Every day, 4627 megagrams of poultry manure are produced in chicken farms in Arkansas (Hishaw, 2006). Poultry litter has a high concentration of phosphorus and nitrogen, making it an ideal amendment to agricultural soils. Applying poultry litter directly onto agricultural fields, however, can lead to ammonia volatilization. When nitrogen is deposited to the soil through wet or dry deposition, it can be conducive to nitrogen loading of lakes, acidification of soils, and damage to crops that are sensitive to changes in nitrogen levels. Not only is ammonia volatilization a hazard of direct application of poultry litter, but land application of poultry litter can also contaminate surface water with a high level of phosphorus (Doydora et al., 2011). This is of major importance in Arkansas, especially in the sensitive Illinois River watershed. Scientists faced with the issue of how to deal with excessive amounts of poultry litter discovered that once poultry litter undergoes pyrolysis to become BC, it not only reduces in volume by 75%, but it becomes a stable soil amendment with seemingly few to no hazardous effects.

Research shows that BC can improve many aspects of growing conditions in the soil, and that poultry litter BC can be very beneficial when pyrolysed. It was hypothesized that our control groups lacking BC would have the shortest height with the lightest weight and smallest leaf area, but plants receiving moderate amounts of BC with additional fertilizer would be the tallest and heaviest with the largest leaf area at time of harvest. It was also hypothesized that the highest rates of BC application would be detrimental to growth for cotton, as has been recorded in previous research found in literature.

MATERIALS AND METHODS

Soil. Soil used in the experiment was Captina silt loam (Typic Fragiudult), a common Arkansas soil with a long history of cropping. It was obtained from the University of Arkansas System Agricultural Research and Extension Center farm in Fayetteville, Ark.

Biochar. The BC employed in the experiment was composed of pyrolysed poultry litter. The poultry litter BC was obtained from a local source, BioEnergy Systems LLC. Once the poultry litter BC was obtained, it was tested for nutrient content, as shown in Table 1.

Cotton Seed. Cotton (*Gossypium hirsutum* L.) cultivar Stoneville 5288 2BRF cotton was planted because it is one of the most common cotton genotypes grown in Arkansas.

Greenhouse Experiment. This study was conducted for eight weeks through October, November and December 2013 in the greenhouse at the Rosen Center at the University of Arkansas. The study used a randomized complete block design with three replications. We began with eighteen 2-L pots. Six treatments were administered to the plants with three replications per treatment. The treatments included 0 kg/ha poultry litter BC with fertilizer (56 kg N/ha), 0 kg/ha poultry litter BC without fertilizer, 1500 kg/ha poultry litter BC with fertilizer, 1500 kg/ha poultry litter BC without fertilizer, 3000 kg/ha poultry litter BC with fertilizer, and 3000 kg/ha poultry litter without fertilizer (Table 2).

As soil was added to the pots, the BC was applied. The same amount of soil, approximately 5.2 kg dry, was added to each pot. The soils were flushed by pouring water through the pots until water was dripping out the bottom and drained for 24 h. Then ten seeds were planted in each pot, and after germination and seedling emergence (approximately 10 days), the most uniform plant in each pot was chosen and the rest were removed. Pots were watered daily to field capacity. Height of each plant was recorded weekly and plants were randomized on the greenhouse bench to avoid any biases. After four and one half weeks, the nitrogen fertilizer urea (46-0-0, 56 kg /ha or 50 lb/ac) was applied to the pots designated for additional fertilizer. After eight weeks of growth, the 18 plants were cut at the soil surface and immediately weighed for fresh weight and their leaf area was measured using a LI-COR leaf area meter (LI-3100C Area Meter, LI-COR Environmental and Biotechnology Research Systems, Lincoln, Neb.), dried in an oven for 48 h, and weighed again.

Statistical Analysis. Data was analyzed using JMP 8.0 from SAS Inc (SAS Institute, Inc., Cary, N.C.). Means were calculated using the student's *t*-test based on least significant differences. Differences were significant at $P = 0.05$.

RESULTS AND DISCUSSION

The plants at 27.52 cm in the BC2 + F treatment were significantly ($P < 0.05$) taller than the control with and without fertilizer groups (Table 3). However, cotton in BC2 + F was not significantly taller than the plants in the other treatments receiving biochar, with or without fertilizer applications. (Table 3).

Fresh weight was highest in the plants in the BC2 +F group at 14.7 g. They were significantly ($P < 0.05$) heavier than the plants in the control +F, control –F, and BC2 –F groups. They were heavier, but not significantly ($P < 0.05$) heavier than the BC1 +F and the BC1 –F groups (Table 3).

The average dry weight was highest in the BC2 +F group at 1.87 g and it was significantly ($P < 0.05$) heavier. than the control +F, control –F, and BC2 –F groups. It was not significantly ($P < 0.05$) heavier than the BC1 +F or BC1 –F groups (Table 3).

The BC2 +F group had the largest leaf area at 419.48 cm^2. It was not significantly ($P < 0.05$) larger than the BC1 +F or BC1 –F groups. However, it was significantly ($P < 0.05$) larger than the group with the smallest leaf area, the control +F group at 176.31 cm^2, the control –F, and the BC2 –F groups (Table 3).

In each seedling growth parameter tested, the control group with fertilizer underperformed compared to the low and high rate of biochar application with fertilizer and the low rate of biochar without fertilizer, showing that even compared to the addition of nitrogen fertilizer alone, BC can aid cotton growth and development. However, the BC–nitrogen interaction was obvious because of the better performance in all the BC +F groups than the control +F groups. The BC1 groups had better growth than the control +F in for all properties measured, but did not grow as well as the BC2+F, which was also significantly greater in plant growth parameters than the control.

Plant height data in our study was both similar and different than that of the data Uzoma (2011) collected in the study with maize (*Zea mays* L.) and cow manure BC on a sandy soil. The tallest plants in that study resulted from an intermediate BC rate of 5000 kg/ha, and the shortest plants from the control (no BC) group (Uzoma et al., 2011). Results from our study indicated that the highest rate of 3000 kg/ha was conducive to tallest height of the three rates used, but it had not reached the overload point Uzoma (2011) discovered. However, in a study conducted with quinoa and peanut hull BC on a sandy soil, results indicated that plant height was unchanged due to BC treatment with reduced water supply (Kammann et al., 2011).

Studies of the relationship between dry weight and BC have a large range of results and require further study. Results from Chan et al. 2007 using radish (*Raphanus sativus*) and greenwaste BC on an Alfisol indicated that BC alone did not increase radish dry weight, however, the highest rate of nitrogen added to all BC rates showed significant increase, confirming the BC-nitrogen interaction again. Our research showed that the BC –F groups did not experience significant differences between rates, but BC +F groups did. However, a year later, Chan (2008) conducted another study with poultry litter BC and radishes. Results indicated that even without nitrogen, BC increased dry weight, even at the lowest rate (Chan et al., 2008).

A study conducted with quinoa and peanut hull BC on a sandy soil indicated that BC application significantly increased leaf area both with a sufficient and a reduced water supply (Kammann et al., 2011). Our research did not demonstrate a leaf area increase in the absence of additional fertilizer. Biochar rates alone did not significantly ($P < 0.05$) increase leaf area.

In summary, the data indicate that the high level BC +F showed significant ($P < 0.05$) increases in plant height, fresh weight, dry weight and leaf area over both controls. It also showed significant ($P < 0.05$) increases in fresh weight, dry weight, and leaf area over the high level BC treatment without fertilizer. Based upon the results of this research, a full-scale, season long, multi-year study of the influence of BC on cotton growth and development would seem justified.

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Table 1. Compositional analysis of BioEnergy Systems, LLC (BES) Biochar.

pH units	**μmhos/ cm**				**mg/kg**				
pH	EC	P	K	Ca	Mg	S	Na	Fe	Mn[1]
10.2	16680	7076	26412	3271	3071	3525	6880	32	190
				mg/kg					
P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu[2]
46915	72298	67904	15298	10486	19919	2453	1397	1261	801
				%TN	%TC[3]				
				3.00	32.02				

[1]pH (1:2 soil ratio), Mehlich-3 extractable (1:10 ratio) Analysis by SPECTRO ARCOS Inductively Coupled Plasma (ICP; Spectro Analytical Instruments GmbH, Kleve, Germany).
[2]Total Recoverable Metals, Environmental Protection Agency (EPA) method 3050, measured on SPECTRO ARCOS ICP.
[3]Total N and C by combustion, Elementar vario MAX (Elementar Analysensysteme GmbH, Hanau, Germany).

Table 2. Biochar and Fertilizer Treatment Combinations.

Treatment	**Description**
Control +F	No biochar – 56 kg/ha N (50 lb/ac N)
Control –F	No biochar – No fertilizer
BC1 +F	1500 kg/ha biochar – 56 kg/ha N (50 lb/ac N)
BC1 –F	1500 kg/ha biochar – No fertilizer
BC2 +F	3000 kg/ha biochar –56 kg/ha N (50 lb/ac N)
BC2 -F	3000 kg/ha biochar – No fertilizer

Table 3. Cotton Physical Data after Eight Weeks of Growth

	Average Height (cm)	Average Fresh Weight (g)	Average Dry Weight (g)	Average Leaf Area (cm^2)
Control +F	19.90 C[1]	6.07 C	0.87 C	176.31 C
Control -F	22.23 BC	8.03 BC	1.03 BC	225.82 BC
BC1 +F	24.55 AB	11.07 AB	1.43 AB	304.98 AB
BC1 -F	25.19 AB	11.37 AB	1.47 AB	312.75 AB
BC2 +F	27.52 A	14.7 A	1.87 A	419.48 A
BC2 -F	24.97 AB	8.47 BC	1.07 BC	215.57 BC

[1]Means in the same column with the same letter are not significantly different at the 0.05 alpha level determined by least significant difference values.

Consumer perceptions of poultry production in Arkansas: Perceptions analysis

Stuart Estes and Leslie D. Edgar†*

ABSTRACT

Poultry production holds an important place in Arkansas economically and as a food source. The importance of poultry production ultimately hinges on the demands of the consumer. With this in mind, this study surveyed consumers to assess their perceptions of poultry production in Arkansas. The instrument, used to survey consumers, was created by the researcher and an expert committee at the University of Arkansas. Consumers were interviewed through direct communication at grocery stores in northwest Arkansas. Data gathered from the study were analyzed for descriptive and correlational statistics. Two key findings were that consumers were unsure about the use of hormones and antibiotics in poultry production, and consumers agreed that poultry production has a positive effect on Arkansas. Based on these descriptive and correlational statistics, recommendations were made for marketing and education efforts to maintain the viability of poultry production in Arkansas. For example, consumers need to be educated about poultry production practices pertaining to conventional production processes, hiring in the poultry industry, and the use of factory farms to produce poultry.

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MEET THE STUDENT-AUTHOR

Stuart Estes

I am an agricultural education, communication and technology major with an emphasis in agricultural communications in the Department of Agricultural and Extension Education. I am a recipient of a 2013 Student Undergraduate Research Fellowship, which was used to fund this study. In the AEED Department, I am an active member of REPS (Representing Excellence, Pride and Service) and the Agricultural Communicators of Tomorrow. After completing my bachelor's degree, I plan on pursuing a master's degree here at the university in Agricultural and Extension Education.

I chose to participate in this research due to my interest in agricultural communications and how the consumers that drive the industry perceive agriculture. I hope that this study will be useful to the poultry industry that is so important to the state. I look forward to continuing research in these areas during my educational career.

I would like to thank Dr. Leslie Edgar, without whom this research would not have been possible.

INTRODUCTION

Arkansas is known for prolific poultry production (Boehler, 2010). With that in mind, because of the poultry industry's reach, it is one of the most important parts of the agricultural economy and also a significant job creator in the region (Goodwin et al., 2002). The poultry production and processing sector in Arkansas contributes 52,867 jobs to the market, and $1.8 billion in added value to the Arkansas economy (Goodwin et al., 2002). Additionally, Arkansas is the second-largest commercial-broiler-producing state in the nation (Boehler, 2010).

Along with the importance of the poultry industry economically and as a job market in Arkansas, chicken is one of the most affordable food products in the United States (American Meat Institute, 2009). As of 2007, the average annual per capita consumption of chicken was approximately 85 pounds (American Meat Institute, 2009). In fact, per capita consumption of poultry has increased dramatically over the last 30 years, from 40.2 pounds per person in 1970 to 86.5 pounds per person in 2007 (American Meat Institute, 2009). Even though prices for poultry at the grocery store have increased over the years—approximately $30 per capita from 1997 to 2007—the increase has been significantly less than other meats such as beef—which had nearly a $75 per capita increase over the same time period (American Meat Institute, 2009).

It is important to have some understanding of what drives consumers to be active in the market. The theory of reasoned action states that human actions are guided by three considerations: (a) beliefs about the consequences of an action (behavioral beliefs), (b) beliefs about the normative expectations of others (normative beliefs), and (c) beliefs about the presence of factors that may promote or hinder the behavior (control beliefs) (Ajzen and Fishbein, 1980). Applying the theory of reasoned action to consumers who purchase poultry, consumers who believe there will be negative consequences associated with purchasing poultry will be less likely to purchase poultry. Also, consumer behavior will be directly influenced by their reference groups and whether or not they purchase poultry products. Finally, consumer behavior will be affected by their beliefs about the availability of poultry products in the area. The theory of reasoned action weighs heavily on the behavior of consumers, but also plays an important role in understanding consumer perceptions.

The importance of poultry production in Arkansas requires that producers and consumers both possess a certain level of knowledge about the processes and methods that constitute this industry. This is especially true in Arkansas where poultry production is important in so many different ways. Agricultural literacy is defined as the possession of "a minimum level of knowledge of the industry which produces and markets food needed for human survival" (Frick et al., 1995).

Much of the research about agricultural perceptions shows that consumers are losing literacy the farther they are generationally removed from the farm. Frick et al. (1995) showed in their study of rural and urban perceptions that respondents living on farms were more knowledgeable about agriculture than their rural non-farm neighbors, who were more knowledgeable than their urban counterparts. As producers and consumers continue to be separated, tensions between the two parties will continue to grow (Wachenheim and Rathge, 2000). A study, conducted with a questionnaire developed by researchers, on university students showed that students perceive the food supply to be safe and agriculture as having a positive impact, but students in the agricultural programs held more favorable views than those students not in the agricultural programs (Terry and Lawver, 1995).

Although a sufficient amount of research exists to show that the general public is losing agricultural literacy (Frick et al., 1995; Terry and Lawver, 1995; Wachenheim and Rathge, 2000), not much research has been conducted to address consumer perceptions of specific areas of agriculture. Because agriculture is a consumer-driven industry, it is important that producers and the industry understand the perceptions held by consumers. This will allow for proactive marketing and public relations activities tailored to inform consumers, and to educate and overcome inaccurate information. This study identified current perceptions held by consumers of one of the most prominent agricultural industries in the state, namely, poultry production.

The purpose of this study was to understand the perceptions of the poultry industry by Arkansas consumers so that educational and marketing recommendations can be made to improve the longevity and acceptance of the poultry industry. It is vital to Arkansas poultry production that producers and consumers see eye-to-eye, as development of agricultural literacy "drives the development of policies which are mutually beneficial for both consumers and producers" (Frick et al., 1995).

MATERIALS AND METHODS

This study used descriptive survey methodology. The survey consisted of 13 questions that assessed consumer perceptions of poultry production in Arkansas, as well as questions to assess consumer knowledge of poultry production and a demographic section. The statistical analysis was descriptive in nature and the instrumentation followed Dillman's Tailored Design method (Dillman, 2007) to ensure accurate question development. The representative sample for this study was consumers in three select areas in northwest Arkansas. A convenience sample of 353 respondents was assessed; there were 198 respondents agreeing to participate. Participants were selected on a random basis through direct communications at grocery stores.

The survey created to conduct this research consisted of three parts: (a) a section that assessed consumer perceptions of poultry production in Arkansas, (b) a section that assessed consumer knowledge of poultry production and the industry, and (c) a demographic section.

Content validity for the survey was achieved by faculty experts from the University of Arkansas reviewing the instrument. Instrument stability for the survey was 0.8 (Gall et al., 2006). Data were assessed for descriptive and correlational statistics using SAS v. 9.3 (SAS Institute, Inc., Cary, N.C). Open-ended responses were analyzed using open coding (Creswell, 2007; Glense, 2006; Strauss and Corbin, 1990).

RESULTS AND DISCUSSION

Respondents were first assessed for their perceptions about poultry production in Arkansas (Table 1.1). Consumers agreed that poultry is more affordable than beef or pork (M = 4.81, SD = 1.09). Consumers believed it is healthier to eat organically produced poultry than conventionally produced poultry (M = 4.47, SD = 1.39). When asked about their perception of hormone and antibiotic use in poultry production, consumers disagreed that hormones and antibiotics were never given to poultry during production (M =1.91, SD = 1.05; M = 1.84, SD = 0.96). Consumers were unsure as to whether conventionally produced poultry contained unsafe levels of hormones or antibiotics (M= 3.68, SD = 1.45). Respondents disagreed that poultry is the cause of most foodborne illness (M = 2.21, SD = 0.99). Consumers moderately agreed that poultry producers care about the welfare of the poultry they produce (M = 4.01, SD = 1.41). Consumers were unsure if farmers use humane production practices (M = 3.81, SD = 1.42). When asked about poultry production's effect on the environment, respondents moderately disagreed that poultry production is harmful to the environment (M = 2.90, SD = 1.30). Consumers were unsure if poultry processing employed a large number of illegal immigrant workers (M= 3.93, SD = 1.36). Respondents moderately agreed that most Arkansas poultry was grown on factory farms (M= 4.15, SD = 1.37). Consumers disagreed that if they lived in a rural area, they would like to live near a poultry farm (M = 2.20, SD = 1.33). Overall, consumers agreed that poultry production has a positive effect on Arkansas (M = 4.92, SD = 1.07).

After respondents were assessed regarding their perceptions of poultry production, they responded to the section of the survey that assessed their knowledge of the poultry industry. Consumers were unsure as to whether they were very knowledgeable about poultry production processes (M = 3.70, SD = 1.36). The majority of consumers surveyed did not work in the poultry industry, nor did any members of their immediate family (M = 1.18, SD = 0.39).

Finally, consumer demographics were gathered as a part of the survey. The average age of respondents was 49.47, ranging from 19 to 92 years old. Most consumers surveyed lived in a suburban area (M = 3.23, SD = 0.99). In regard to education level, respondents possessed an average education of an associate degree (M = 3.91, SD = 1.46). The majority of respondents were women (M = 1.65, SD = 0.48). Correlations between demographics and perceptions can be found in Table 1.1.

Recommendations for marketing and consumer education were made based on the data collected in this study. First, consumers need to be educated about poultry production practices pertaining to conventional production processes, hiring in the poultry industry, and the use of factory farms to produce poultry to improve agricultural literacy (Frick et al., 1995) and ultimately ensure the importance of poultry production in Arkansas (Goodwin et al., 2002). Second, consumer education efforts must adequately address the use of antibiotics and hormones in poultry production due to the finding that consumers make purchases based on the perceived health benefits of poultry, as detailed in the theory of reasoned action, which states that consumers make decisions based on the consequences associated with a purchase (Ajzen and Fishbein, 1980). These recommendations should prove helpful to the poultry production industry as it strives to remain viable in Arkansas.

This study to assess consumer perceptions of poultry production in the state of Arkansas revealed consumer perceptions in regard to a variety of parts of the poultry production industry. Consumers held mostly unfavorable perceptions regarding conventional production processes, hiring in the poultry industry, and the use of factory farms to produce poultry; however, consumers viewed poultry as a more inexpensive food source, and also perceived poultry production as having an overall positive influence on the state. The perceptions found in this study should be used to more effectively tailor marketing and education efforts to maintain the importance of poultry production in Arkansas through improving agricultural literacy (Frick et al., 1995).

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Table 1. Consumer perceptions and relationships between statements and demographic characteristics.

Statement	Mean	Standard Deviation	Knowledge[a]	Industry Affiliation[b]	Age[a]	Area of Residence[c]	Education[c]	Gender[b]
			Relationships between Statements and Demographic Characteristics					
Poultry is more affordable than beef or pork.	4.81	1.09	-0.01	0.11	0.21**	0.04	0.00	-0.04
It is healthier to eat organically produced poultry than conventionally produced poultry.	4.47	1.39	-0.06	0.05	-0.12	-0.05	-0.09	-0.04
Hormones are never given to poultry.	1.91	1.05	0.13	0.07	-0.07	0.05	-0.12	-0.15*
Antibiotics are never given to poultry.	1.84	0.96	0.03	0.05	0.08	-0.10	-0.11	-0.12
Conventionally produced poultry contains unsafe levels of hormones or antibiotics.	3.68	1.45	0.15	-0.02	0.08	0.02	-0.09	0.19**
Eating poultry is the cause of most food-borne illness.	2.21	0.99	0.04	-0.05	-0.12	-0.09	-0.07	0.15*
Poultry producers care about the welfare of the poultry they produce.	4.01	1.41	-0.04	0.16*	0.08	-0.03	-0.08	-0.03
Poultry farmers use humane production practices.	3.81	1.42	0.03	0.17*	0.11	-0.04	-0.09	0.04
Poultry production is harmful to the environment.	2.90	1.30	-0.03	-0.11	-0.03	0.11	0.15*	0.12
Poultry processing employs a large number of illegal immigrant workers.	3.93	1.36	0.08	-0.07	0.003	0.05	-0.21**	0.11
Most Arkansas poultry is grown on factory farms.	4.15	1.37	0.01	-0.10	-0.03	0.06	-0.04	-0.04
If I lived in a rural area, I would like to live near a poultry farm.	2.20	1.33	0.11	0.18	-0.07	-0.17	-0.14	-0.07
Overall, the poultry industry has a positive effect on Arkansas.	4.92	1.07	0.04	0.09	0.10	-0.10	-0.05	-0.11

[a]Pearson Product-Moment Correlation.
[b]Point by Serial Correlation.
[c]Spearman Rank-Order Rho.
Notes: N = 198; Likert Scale is 1 = Strongly Disagree; 2 = Disagree; 3 = Moderately Disagree; 4 = Moderately Agree; 5 = Agree; 6 = Strongly Agree; $*P < 0.05$; $**P < 0.01$.

Assessment of students' crisis communications skill increase based on classroom instruction and Second Life™ training

Gregory C. Jernigan, Jessica R. England†, and Leslie D. Edgar§*

ABSTRACT

Crisis communication training and skill development are critical to ensure the sustainability of the agriculture industry. The purpose of this study was to assess students' perceptions of knowledge, ability, and skills on select crisis-related skills, tasks, and activities in order to identify the potential effectiveness of a Second Life™ (SL) simulation. Pre- and post-test data were collected to determine the potential changes in skill in the seven crisis communication constructs of (a) related knowledge; (b) mass, group, and intrapersonal communications; (c) contingency planning; (d) use of related supplies and tools; (e) identifying learning and training needs; (f) related areas of expertise; and (g) personality traits. Participants also identified their SL Performance Expectancy as it pertained to crisis communications training. Of the population of study (N = 15), 12 usable pairs (n = 12) were analyzed and described in the findings. Participants identified their current competency level in each of the crisis communication skill areas using a 6-point Likert-type scale that ranged from "no knowledge/experience" to "expert". A grand mean was calculated for each construct with differences between pre- and post-test scores being examined. The resulting difference in each of the seven crisis communication constructs represented a large effect when comparing pre-test/post-test scores. Based on data, participants increased in knowledge, ability, and skills on associated items. Each item could be used to improve a communicator's ability to effectively manage a crisis. Virtual worlds appear to be an effective training mechanism and additional research should be focused in this area.

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MEET THE STUDENT-AUTHOR

Gregory C. Jernigan

I am from the Searcy area and graduated from Searcy High School in 2008. I graduated from the University of Arkansas with a bachelor's degree in Agricultural Business in May 2013. Throughout my collegiate career, I have been involved in multiple organizations including Sigma Pi Fraternity International.

I plan to begin my M.S. degree program in Agricultural Economics in the fall of 2013 under the guidance of Dr. Jennie Popp. My concentration will lie in finance.

I would like to give special thanks to Dr. Leslie Edgar, the mentor of this project. Without her guidance this would not have been possible. I will be forever grateful for the opportunities she created throughout this research.

INTRODUCTION

Crisis communication management is an important aspect of the agricultural industry, particularly because agriculture is crucial to human existence (Edgar et al., 2012a). Agricultural progress and success can be hindered by a variety of environmental, economical, and social issues. In such situations, "communication professionals must be prepared to manage the people involved with the crisis and reduce negative impacts" (Edgar et al., 2012a, p. 1). Crises are inevitable, especially in the agricultural sector. Therefore, knowing how to combat these issues and maintaining a favorable image to the public is vital to agricultural success. Individuals must be armed with skills in crisis communication through thorough training so that messages can be disseminated effectively (Edgar et al., 2012a).

Extensive research has been conducted regarding the use of technology in education (Kotrlik and Redmann, 2009; Kotrlik et al., 2003; Murphrey et al., 2009). Agriculturally related technologies have expanded over the past decade, and virtual education can be used as a key component. Training individuals using various forms of technology, such as Second Life™, may play a key role in preparing crisis communicators for the agricultural industry. Second Life™ can be used to encourage experiential learning (Leggette, et al., 2012b), because it incorporates real world situations and uses them in the classroom as an educational tool (Bowers, et al., 2009; Johnson, 2006). Second Life™ instructional potential exists, although research on its capabilities is narrow at this time (Leggette et al., 2012a).

The purpose of this study was to assess students' perceptions of knowledge, ability, and skills on select crisis-related skills, tasks, and activities in order to identify the potential effectiveness of a Second Life™ simulation. Objectives included a pre- and post-assessment of the following: (1) determine graduate students' perceptions of knowledge, ability, and skills on select crisis communications competencies and (2) determine graduate students' perceived expectancy performance on select Second Life™ tasks used to enhance crisis communications competencies.

MATERIALS AND METHODS

The population of the study consisted of students enrolled in a crisis communications course at Texas Tech University during fall, 2011 (N = 15). Prior to curriculum being taught, students completed a questionnaire regarding perceptions of knowledge, ability, and skills on skills, tasks, and activities related to crisis communications. After completion of the course and after participating in a virtual crisis simulation using Second Life™, students completed a post-assessment of perceptions of knowledge, ability, and skills on the same competency areas.

Questionnaires referenced critical crisis communication topics and skills as identified in a Delphi study involving crisis communication experts throughout the U.S. and Canada (Edgar et al., 2012b). The instrument consisted of seven constructs including: Knowledge, Communication Skills, Contingency Plans, Supplies and Tools, Learning and Training Needs, Area of Expertise, and Personal Traits. Second Life™ Performance Expectancy was also assessed. Individual items for each construct were scaled statements ranging from either "no experience/knowledge" (1) to "expert" (6). All data for selected constructs were summated and inferential analyses were performed using Cohen d (IBM SPSS 20.0.), which is an effect size used to indicate the standardized difference between two means, in this case the pre-test M and the post-test M. The "descriptor" denotes the strength of the effect. Of the population of study (N = 15), 12 usable pairs (n = 12) were analyzed and described in the findings.

RESULTS AND DISCUSSION

The following results demonstrate the assessment of students' perceptions of knowledge, ability, and skills associated with crisis communication expertise, and the use of Second Life™ as a means to train students to manage crises in agriculture. Participants were predominately Caucasian, master's degree seeking students. Students' responses after instruction completion were significantly different than before the implementation of the treatment (crisis communications course). Mean differences between the two data collection points were calculated and resulting standard deviations and effect sizes were noted (Table 1). In all seven competency areas, large effects between mean differences were found. Each of the seven competency area scores for participants were summated and results are shown in Table 1. Each competency area contained seven to 16 statements that were used to determine the summated score.

Participants were asked to identify their Second Life™ Performance Expectancy based on 19 specific items, which were assessed using a 6-point Likert-type scale that ranged from "strongly agree" (6) to "strongly disagree" (0). The largest effect size was noted in "I intend to use Second Life in the next 12 months" ($M = 3.00$, $SD = 1.00$, $d = 3.00$, Table 2). The remaining 18 Second Life™ performance expectancy statements with corresponding mean differences, standard deviations, and effect sizes were reported.

Data revealed a large effect size for each of the seven crisis communications competency areas assessed. This indicated a significant increase in each competency between pre- and post-tests. While participants did not indicate a certain intention to use Second Life™ in the next 12 months, participants did increase in knowledge, ability, and skill level on associated items needed to effectively manage a crisis. Materials and topics covered increased the abilities of students enrolled in the course based on previously identified critical crisis communication topics and skills (Edgar et al., 2012b). Future research should focus on the value of virtual simulations and how technology selection and acceptance impacts learning. The importance of utilizing Second Life™ as a platform for educational experiences should be assessed in relation to the creation of superior learning experiences as compared to those not offering virtual components (Mason, 2007). This research demonstrated virtual education as an effective tool in training communicators. Additional research should explore virtual educational platform usage at other universities. The value of virtual training methods for crisis communication education should be explored in relation to assessing perceptions of knowledge, ability, and skills of participants, especially those involved in disseminating information to the public.

The significance of this study for international agricultural and extension education relates to the potential to use technology effectively to deliver crisis communication training. Arming individuals with skills in crisis communication enables effective communication in times of dire need especially in international settings. This study provides key findings to enable agricultural and extension educators to understand the importance of crisis communication and methods to achieve related training.

ACKNOWLEDGEMENTS

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Table 1. Difference in competency areas through course intervention.

	M^a		*SD*			
Competency	**Pre-test**	**Post-test**	**Pre-test**	**Post-test**	**Cohen's *d***	**Cohen's *d* descriptor**
Knowledge	2.53	4.59	0.82	0.98	1.57	Large
Communication	3.53	4.66	0.86	0.76	1.12	Large
Contingency	1.48	4.40	1.15	1.19	1.71	Large
Supplies	2.00	4.75	1.18	1.02	1.91	Large
Learning	1.56	4.36	1.22	0.97	2.17	Large
Expertise	2.88	4.67	0.94	0.95	1.38	Large
Personality	4.06	4.96	0.87	0.64	0.92	Large

Notes: M^a = mean difference between pre- and post-assessments; 0 = No Knowledge/Experience; 1 = Entry; 2 = Novice; 3 = Proficient; 4 = Skilled; 5 = Mastery; 6 = Expert. Competency areas were summated and grand means were used to calculate mean differences.

Table 2. Second Life (SL) performance expectancy statements.

Competency	*M* Pre-test	*M* Post-test	*SD* Pre-test	*SD* Post-test	Cohen's *d*	Cohen's *d* descriptor
Using SL in my education would enable me to accomplish assignments more quickly.	3.00	4.00	1.41	1.58	1.42	Large
Using SL would enhance my effectiveness in learning.	3.60	5.20	1.52	0.84	1.79	Large
Using SL would make it easier to do my assignments	3.40	4.40	1.52	1.52	1.00	Large
I would find SL useful in my education.	3.60	5.60	1.51	1.14	2.85	Large
If I use SL, I will spend less time on routine assignments.	3.60	3.80	0.89	1.30	0.15	Small
Learning to operate SL would be easy for me.	4.40	5.20	1.51	1.09	0.61	Large
My interaction with SL would be clear and understandable.	3.80	5.20	1.10	1.48	0.92	Large
I would find SL flexible to interact with.	3.60	4.40	1.14	1.34	1.81	Large
It would be easy for me to become skillful at using SL.	4.00	5.20	1.22	1.09	0.67	Large
I would find SL easy to use.	3.60	4.60	1.14	1.67	1.00	Large
Using SL takes too much time from my normal assignments.	3.60	3.60	1.14	1.82	0.00	Trivial
Overall, I believe that SL is easy to use.	3.60	4.80	0.89	1.79	1.10	Large
People who are important to me think that I should use SL.	4.40	4.00	0.89	1.41	0.23	Small
I have the resources necessary to use SL.	5.00	5.40	1.00	1.34	0.35	Large
I have the knowledge necessary to use SL.	3.80	5.00	1.09	0.71	0.73	Large
Given resources, opportunities and knowledge it takes to use SL, it would be easy for me to use SL.	4.60	5.20	1.14	1.64	1.11	Large
I think that using SL fits well with the way I like to learn.	3.40	4.60	1.34	1.51	1.10	Large
Using SL fits into my learning style.	3.20	4.60	1.10	1.52	1.22	Large
I intend to use SL in the next 12 months.	6.00	3.00	1.00	1.22	3.00	Large

Note: 0 = Strongly disagree; 1 = Disagree; 2 = Moderately disagree; 3 = Neither agree nor disagree; 4 = Moderately agree; 5 = Agree; 6 = Strongly agree.

Short-Term denitrification in the metalimnion of a eutrophic reservoir

Aki Kogo, Erin M. Grantz†, and J. Thad Scott§*

ABSTRACT

Denitrification in metalimnetic water was examined under different conditions to determine how addition of nitrate (NO_3^-) and particulate carbon (PC), aeration, and concentrations of nitrate affect denitrification. In the first experiment, water samples from a metalimnion were treated with different combinations of NO_3^- and PC. Changes in excess N_2-N concentration for 10 days were measured using membrane inlet mass spectrometry (MIMS). The second experiment used the same treatments as the first experiment after aeration of water. Besides excess N_2-N concentrations, O_2 concentrations were measured for 16 days. The third experiment examined how different initial concentrations of NO_3^- influenced denitrification; and changes in the samples with the four different concentrations of NO_3^- were measured using MIMS for 42 days. The first experiment indicated that all samples in this experiment had completed denitrification before this experiment, and denitrification occurred only in the samples added with NO_3^-. An aeration event in the second experiment resulted in low initial excess N_2-N concentrations; and excess N_2-N concentrations increased most in the samples containing both PC and NO_3^- and second most in PC amended samples. Excess N_2-N concentrations did not increase in other two treatments, indicating the effect of PC on creating anoxic conditions for denitrification. Differences in initial NO_3^- concentrations did not result in differences in denitrification. This study showed denitrification in metalimnion can be enhanced by adding NO_3^- and PC and by repeating oxic and anoxic condition of water, which can be a way to remove nitrogen from aquatic systems.

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MEET THE STUDENT-AUTHOR

Aki Kogo

I am from Nara, Japan. I have been very interested in global environmental issues since I was in high school, and that was why I decided to study in the United States with a purpose of studying both environmental science and English. I came to Fayetteville four years ago and am finishing my major in Environmental, Soil, and Water Science in May 2013. I struggled with English, but I am glad that I have improved my English through studying in this university. From this fall, I am going to continue my education in the civil engineering program at University of Toronto.

I started this project in the summer of 2009. I learned a lot from this experience and enjoyed doing this research with my mentor, Dr. Thad Scott, and students in his lab. I am very thankful to Dr. Scott for his guidance and support in this research, and Dr. Savin, Dr. Brye, and Dr. Rom for suggestions in revising my thesis.

INTRODUCTION

As the human population grows rapidly, the effects resulting from anthropogenic activities have been significantly intensified. Reactive nitrogen is one substance that has been released into the environment with increasing amount in recent years. Since 1970, the creation of reactive nitrogen has increased by 120%, while the human population has grown by 78% (Galloway et al., 2008). Many human activities contribute to the increase of reactive nitrogen at both local and global scales; and the major activities causing this problem are the use of nitrogenous fertilizers, burning of fossil fuels, power generation plants, and industries (Vitousek et al., 1997). Among those activities, the use of nitrogenous fertilizer accounts for the largest amount of newly created anthropogenic nitrogen in the environment (Vitousek et al., 1997). Even though application of nitrogenous fertilizers has significantly increased yields of agricultural crops, at the same time excess nitrogen has caused negative effects in the environment. In addition, reduction in vegetated areas has decreased biological nitrogen fixation by about 10%, contributing to the alteration of the nitrogen cycle due to human activities (Seitzinger et al., 2006). The human-induced increase in nitrogen in the environment has brought many negative consequences in the environment.

Eutrophication and Other Effects Resulting from Nitrogen Enrichment. There are negative environmental effects resulting from global nitrogen cycle alteration, including the enlarging Gulf of Mexico hypoxia and an increasing concentration of nitrous oxide in the atmosphere (Schlesinger, 2009). Changes in aquatic systems can be more rapid than in other systems and have serious effects on human societies and the whole ecosystem, including animals, fish, and other organisms. Excessive amounts of nitrogen in the environment often lead to eutrophication in aquatic ecosystems, which often is followed by harmful algal blooms, anoxia/hypoxia, and contamination of drinking water (Galloway et al., 2008). Excess nitrate and resulting eutrophication in the water systems often lead to fish kills, significant loss of sensitive organisms, and loss of biodiversity in aquatic environments and also damage commercial fisheries due to lower oxygen concentrations than the optimum (Rabalais et al., 2002).

Denitrification and Nitrogen Elimination in Lakes. Nitrogen removal from lakes is mostly derived by two processes: sediment burial of particulate nitrogen and atmospheric emission of nitrogen gas via denitrification (Seitzinger, 1988). Denitrification is a process by which facultative anaerobic bacteria reduce nitrate ultimately to nitrogen gas. This process is responsible for about 80% of total nitrogen removal from a lake (Nõges et al., 1998; Galloway et al., 2008). Therefore, denitrification is a potential way to control and mitigate eutrophication in aquatic systems which receive large anthropogenic nitrogen loadings (Seitzinger, 1988). Among aquatic systems, small lakes (<50 km^2) account for nearly half of the global denitrification amount (Harrison et al., 2009). Additionally, Harrison et al. (2009) also reported that reservoirs remove approximately 33% of total N inputs from lentic systems, while occupying only 6% of the total lentic surface area. Freshwater impoundments have an important role in nitrogen elimination from water bodies, and there are many studies focusing on nitrogen burial and denitrification in the epilimnion and hypolimnion, the upper and lower layers of a lake, respectively. However, comparatively little work has been done to measure the amount of denitrification occurring in a metalimnion, the middle layer of a lake. The objective of this study was to measure the amount of denitrification occurring in the metalimnion of Lake Fayetteville, Arkansas under varying nitrate concentrations.

We hypothesized that 1) nitrogen gas concentration in the sample water which was closed to atmospheric exchange would increase through time due to denitrification, and 2) nitrogen gas concentration would be higher in the samples with a higher initial nitrate concentration. The first hypothesis was based on the assumption that, without atmospheric exchange, anoxic conditions in the metalimnetic water would be maintained, and therefore microbial denitrification would occur, consuming nitrate and increasing excess N_2-N concentrations in the samples through time. The second hypothesis was based on the assumption that denitrification continues as long as the water contains nitrate. Therefore, water samples with a greater initial concentration of nitrate would result in a higher dinitrogen gas concentration by the end of experiment.

MATERIALS AND METHODS

Study Site. Lake Fayetteville is a small eutrophic reservoir with an area of 0.604 km^2, and is located in northwest Arkansas, U.S. (36.08 N, 94.08 W). Lake Fayetteville is a flood control impoundment, which is mainly fed by water from urban and agricultural lands. In this study, we focused on denitrification in the metalimnion of Lake Fayetteville. Water samples were obtained from the point which has the deepest depth in the lake, since this point is considered to be most well-stratified and have a thick metalimnion. Also, this point is considered to represent the whole lake because it is close to the outlet of the lake.

To determine the location of the metalimnion, a YSI sonde (YSI Incorporated, Yellow Springs, Ohio) was used to obtain the vertical temperature and dissolved oxygen profile of Lake Fayetteville. The metalimnion was defined as the layer of water in which a temperature change exceeded 1 °C per m depth, which was approximately between 2- and 4-meter depth (Fig. 1). Water was collected from the metalimnion using a Van Dorn sampler and returned to the laboratory for experimental determinations of denitrification potential. In addition to metalimnion water, a water sample was also collected from the epilimnion to supply the particulate carbon (PC) for Experiment 1. In the three experiments conducted in this study, samples were not replicated except for initial samples, which represented the starting condition of each experiment because of the limited number of BOD bottles for the experiments. Also, this study used membrane inlet mass spectrometry (MIMS) to determine N_2 concentrations in water bodies, according to a study conducted by Deemer et al. (2011).

Experiment 1: Effects of Nitrate and Particulate Carbon on Denitrification. Experiment 1 was conducted to evaluate how addition of particulate carbon (PC) and nitrate (NO_3^-) affect denitrification in the metalimnetic water. BOD bottles were prepared before field sampling to have four groups: 1) bottles with no treatment for control, 2) bottles with NO_3^- addition to have 1 mg NO_3^--N/L above the original concentrations of NO_3^- and PC in the water (background), 3) bottles with the same concentration of NO_3^- above background and PC addition to have 5.7 mg-C/L above background, and 4) bottles with PC of 5.7 mg-C/L above background. Bottles were transported in a cooler with ice. Lake water was collected from the metalimnion by a Van Dorn sampler and directly poured into the bottles. Also, 3 bottles were treated with $ZnCl_2$ to preserve the condition of the lake water at the time of sampling. All bottles were sealed immediately after the water was poured into the bottles to prevent air exchange, and then stored in an incubator at 15 °C. The ratios of dissolved nitrogen gas to argon (N_2:Ar), and oxygen gas to argon (O_2:Ar) of one set of bottles were measured by MIMS on days 1, 3, 5, 7, and 10. The bottles were kept in water which had the same temperature as incubation to minimize temperature change. Detail for the complete MIMS setup was as described in Kana et al. (1994). Since the concentration of Ar only depends on the temperature of the water, the concentrations of N_2 gas in the samples were calculated using the N_2:Ar ratio detected by MIMS and Ar concentration at the incubated temperature. The N_2 concentrations ($[N_2]_{SAMPLE}$) in the samples were calculated using the equation below according to the study by Grantz et al. (2012),

$$[N_2]_{sample} = (N_2{:}Ar_{sample} \times [Ar]_{exp}) \left(\frac{[N_2]{:}[Ar]_{exp}}{N_2{:}Ar_{standard}} \right)$$

where $N_2{:}Ar_{sample}$ is the ratio in the sample measured by MIMS, $[Ar]_{exp}$ and $[N_2]{:}[Ar]_{exp}$ are the theoretical concentration and ratio at the incubated temperature, and

N_2:$Ar_{standard}$ is the ratio of air saturated deionized water. Also, the equation for excess N_2 concentration ($[N_2]_{excess}$) is as expressed in Grantz et al. (2012),

$$[N_2]_{excess} = [N_2]_{sample} - [N_2]_{exp} - \min[N_2]_{excess}$$

where $[N_2]_{sample}$ is the N_2 concentration in the sample which is calculated using the previous equation, $[N_2]_{exp}$ is a theoretical N_2 concentration at the incubated temperature, and $\min[N_2]_{excess}$ is the lowest N_2 concentration among all the samples in this experiment. Data analysis was done in Statistical Analysis Systems (SAS) v. 9.3 (SAS Institute, Inc., Cary, N.C.) to determine if each treatment had a significantly different result from other treatments. In this analysis, samples were considered as being replicated through time, and mean excess N_2-N concentration of each treatment was calculated.

Experiment 2: Effects of Nitrate and Particulate Carbon on Denitrification Following an Aeration Event. Experiment 2 was conducted to observe changes in concentrations after metalimnion water was oxygenated and allowed to go anoxic again. Sample water from the metalimnion was collected in a 20-L container and aerated in the laboratory overnight to oxygenate the water and remove excess N_2 from the sample. Also samples were obtained and preserved using $ZnCl_2$ to preserve the initial condition. Then, the aerated water was poured into BOD bottles, which consisted of: 1) bottles with no treatment for control, 2) bottles with NO_3^- addition to have 1 mg NO_3^--N/L higher than the sample water after aeration, 3) bottles with NO_3^- (1 mg NO_3^--N/L) and PC addition to have 7.1 mg C/L, and 4) bottles with PC of 7.1 mg C/L. All bottles were stored in the incubator at 15 °C, and the ratios of N^2:Ar and O_2:Ar of one set of bottles were measured by MIMS at 1, 2, 5, 8, 13, and 16 days after starting the incubation. The concentrations of excess N_2-N in the samples were calculated the same way as described for Experiment 1. The O_2 concentrations in the samples were also calculated using a similar equation. Data analysis was done in SAS v. 9.3 to estimate rates of denitrification in different treatments by linear regression analysis on excess N_2-N concentrations vs. time.

Experiment 3: Long-Term Effect of Nitrate Concentrations on Denitrification. Experiment 3 was conducted to determine how difference in NO_3^- concentration influences denitrification in the water. Sample water from the metalimnion was collected into a 20-L container and aerated for two days. Then, the water was poured into the BOD bottles which consisted of: 1) 0 mg NO_3^--N/L, 2) 1 mg NO_3^--N/L, 3) 2.5 mg NO_3^--N/L, and 4) 5.0 mg NO_3^--N/L higher than the NO_3^--N concentrations after aeration, respectively. All bottles were amended with PC to have 7.1 mg C/L. Samples for initial conditions were also collected and preserved using $ZnCl_2$. All bottles were stored in a water bath at room temperature. The ratios of N_2:Ar and O_2:Ar were measured with MIMS at days 1, 5, 10, 15, 25, 33 and 42 after starting incubation. The concentrations of excess N_2-N and O_2 were calculated as described for Experiments 1 and 2.

RESULTS AND DISCUSSION

Experiment 1. Changes in excess N_2-N concentrations in the samples were observed from day 0 to day 10 (Fig. 2a) in Experiment 1. The average excess N_2-N concentration in all samples was 89.6 µmol/L (±standard deviation 10.0 µmol/L) at day 0. Samples with both nitrate (NO_3^-) and particulate carbon (PC) increased to 142 µmol/L excess N_2-N by the end of the measurement, which was the highest concentration among the four treatments. Samples with only NO_3^- had the second most production of N_2 of 121 µmol/L at day 10. The unamended (control) and samples with only particulate carbon resulted in the smallest changes of excess N_2-N concentrations and were 102 µmol/L and 105 µmol/L, respectively.

The mean excess N_2-N concentrations of for the four treatments, F value, and P value were calculated by SAS (Fig. 2b). The mean excess N_2-N concentrations of unamended control and PC amended samples were not statistically different from each other, while samples amended with NO_3^- and with both PC and NO_3^- were significantly different from each other and from unamended control and PC amended samples. The mean excess N_2-N concentrations of the four treatments had a F value = 23.2 and $P < 0.0001$.

Experiment 2. The average initial concentration of excess N_2-N in the samples was 19.6 µmol/L with the standard deviation ± 2.4 µmol/L (data not shown). Samples amended with both NO_3^- and PC showed a rapid increase in the concentration of excess N_2-N (Fig. 3) with the highest concentration on day 16. Samples with PC resulted in the second highest concentration of excess N_2-N by the end of the experiment. Samples amended with NO_3^- and the unamended control resulted in 4.1 µmol/L and 0.0 µmol/L, respectively. Dissolved oxygen (O_2) concentrations started to decline immediately after the experiment started (Fig. 4). Samples amended with PC and NO_3^- and only with PC showed a rapid decline in O_2 concentrations and reached 2.8 µmol/L and 4.0 µmol/L, respectively, which were anoxic conditions. Unamended controls and samples amended with nitrate had slower declines in dissolved O_2 concentrations and did not reach anoxic conditions by day 16. Concentrations of dissolved O_2 in the unamended control and samples amended with NO_3^- were 179 µmol/L and 177 µmol/L, respectively. The rate of denitrification was greatest in the samples amended with both PC and NO_3^- and was 3.18 μmol/L/day (t = 8.0726, P = 0.0013, and r^2 = 0.9422). Samples amended with PC had the rate of denitrification 1.41μmol/L/day (t = 3.1290, P = 0.0352, and r^2 = 0.7099). The unamended control and sample amended with NO_3^- did not have significant difference due to the treatments (control: t = -2.2538, P = 0.0873 and NO_3^-:t = -0.1089, P = 0.3296).

Experiment 3. Changes in dissolved O_2 concentrations and excess N_2-N concentrations in samples with different nitrate concentrations were measured from day 0 to day 42 in Experiment 3. The concentrations of excess N_2-N gas rapidly increased in all samples from the initial concentrations (Fig. 5) with a simultaneous decline in dissolved O_2 concentrations up to day 15 (Fig. 6). The excess N_2-N gas concentrations reached a peak when the samples became anoxic at day 15 and ranged between 68.7 and 74.1 μmol/L for all treatments. After day 15, the concentrations of excess N_2-N gas in all treatments declined rapidly until day 33. Only samples without NO_3^- addition (control) showed a slight increase in excess N_2-N concentrations in this period from day 33 to day 42 and resulted in 26.5 μmol/L by day 42. All other treatments continued to show a decline in the excess N_2-N concentrations until day 42. The N2 concentrations were 4.2 μmol/L in the samples amended to have a 1 mg/L NO_3^- concentration, 3.7 μmol/L in the 2.5 mg NO_3^-/L samples, and 0 μmol/L in the 5 mg NO_3^- /L samples. The declines after day 33 were steeper in the samples with additions of higher NO_3^- concentrations. In this experiment, all the samples showed a rapid decline in dissolved O_2 concentrations and went anoxic after day 15. After day 15 (Fig. 6), dissolved O_2 concentrations remained low throughout the experiment. The changes in dissolved O_2 in the four treatments were all similar. Also, the samples of the four treatments showed similar changes of excess N_2 production.

Factors Affecting Denitrification. Excess N_2-N concentrations increased in the samples which were kept closed to atmospheric exchange and in which dissolved O_2 concentration declined to a low enough level for denitrification to occur. In experiment 1, the unamended control and samples amended with PC did not show much increase in excess N_2-N concentrations over the 10-day experiment. Since samples were not aerated in this experiment, the water was likely anoxic since the time of sampling and denitrification occurred before this experiment, resulting in high excess N_2-N concentrations in all samples throughout the experiment. With low background NO_3^- in the water, only the two treatments with NO_3^- addition resulted in denitrification and increased in excess N_2-N concentrations. The slight increase in excess N_2-N concentrations from the time 0 which was seen in all samples may have resulted from aeration, which would allow nitrification to occur in the early incubation, when the water was transported from the Van Dorn sampler into the bottles.

In Experiment 2, initial aeration decreased the dissolved N_2 concentration and increased the dissolved O_2 concentration as dissolved gases in water came into equilibrium with the atmosphere. The increase in dissolved O_2 concentration in the sample allowed nitrification to occur, which converted ammonium (NH_4^+) to NO_3^-. Thus, the samples in Experiment 2 resulted in the lower concentrations in N_2-N than Experiment 1 and had nitrate available for denitrification to occur. The unamended control and samples with NO_3^- addition had slower decline in their O_2 concentrations and did not become anoxic during the period of this experiment. Since unamended control and NO_3^- amended samples did not develop anoxic conditions required for denitrification, denitrification did not occur in those samples, keeping excess N_2-N concentrations low. Both treatments amended with PC resulted in faster declines in O_2 concentrations than the unamended control and samples amended only with NO_3^-, which showed that carbon addition resulted in more biological activity, consuming the oxygen and promoting the anaerobic process of denitrification in the samples. Concentrations of excess N_2-N increased most rapidly in the samples with both NO_3^- and PC addition, in which PC helped the water become anoxic and the higher nitrate concentrations increased the total amount of denitrification.

From this result, it is concluded that the unamended control and samples only amended with PC in experiment 1 also did not have anoxic conditions and nitrate, both of which are required for denitrification, during the experiment. Therefore, those two treatments resulted in no significant increase in excess N_2-N concentrations. In both experiment 1 and 2, samples amended with both NO_3^- and PC resulted in the highest excess N_2-N concentrations among the four treatments, indicating the addition of PC and NO_3^- can stimulate denitrification. From Experiment 2, PC not only stimulated denitrification but also was necessary to develop anoxic conditions in water before denitrification started.

Nitrate Concentrations and Denitrification. Initial NO_3^- concentration differences in the samples did not affect excess N_2-N concentrations. The changes in excess N_2-N concentrations were similar among all treatments, except in the last part of the experimental period in Experiment 3. Since the samples with no nitrate addition (0 mg/L) had almost the same increase in the N_2 concentration as other three treatments with addition of NO_3^-, it can be concluded that the metalimnetic water either had much more nitrate than the concentrations added in Experiment 3 or had other factors inhibiting consumption of added NO_3^- for denitrification. In Experiment 3, dissolved O_2 concentrations declined to anoxic levels in all samples, and concentrations of N_2 increased due to denitrification as the dissolved O_2 concentrations declined. One possible explanation for the decline in the excess N_2-N concentrations after day 15 is that methanogenesis may have occurred in the samples, creating methane gas in the BOD bottles. Since methane is very insoluble in water, it accumulated in the top of the bottles as bubbles. Excess N_2 gas could diffuse into the methane bubbles, decreasing excess N_2-N concentrations in the sample water. However, this study did not clarify if this mechanism was responsible for the decrease in excess N_2-N concentrations and it would have been necessary to measure methane concentrations to confirm if methanogenesis occurred in this condition.

In conclusion, additions of PC and NO_3^- can stimulate denitrification and increase excess N_2-N concentration in metalimnetic water because PC enhances biological activity and NO_3^- increases the total amount of denitrification. Particulate carbon was also important in creating anoxic condition in water so that denitrification occurred when water was aerated and initially had an oxic condition. To confirm the mechanism of the decline in excess N_2 concentration during the 40-day long experiment, methanogenesis also needs to be studied in future research. From this study, it is implicated that a metalimnion can be a hotspot of denitrification because a metalimnion can be managed so that metalimnetic water has a repeating cycle between oxic and anoxic conditions by mixing waters of the epilimnion and metalimnion. By repeating the cycle, significant N can be removed in metalimnion through denitrification.

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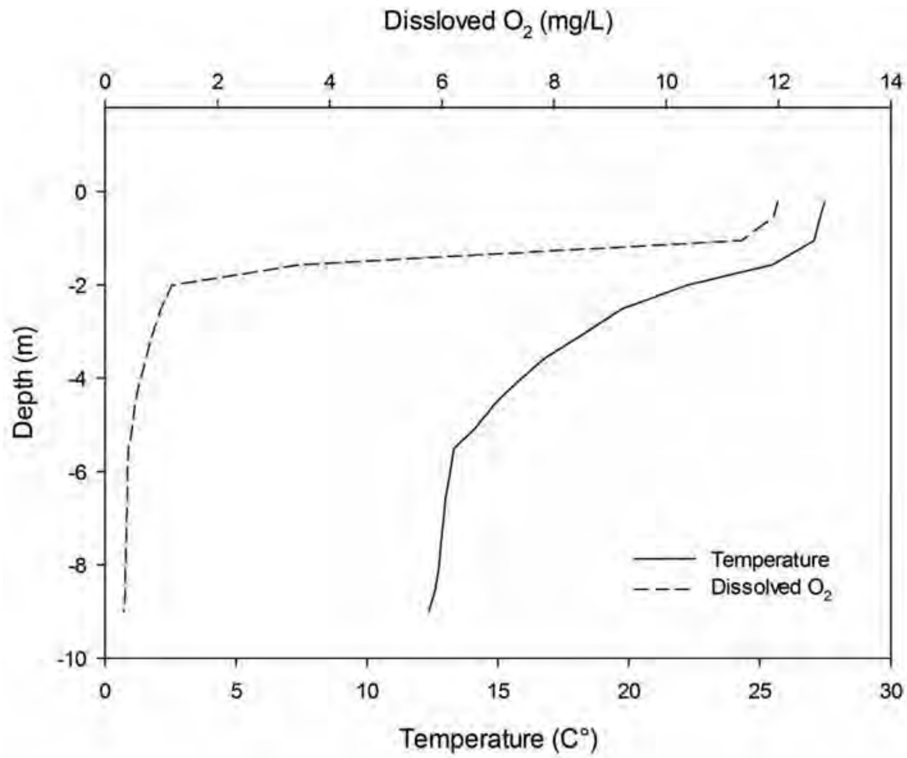

Fig. 1. A profile of Lake Fayetteville of changes of temperature and dissolved O_2 concentration with depth. The metalimnion was located between approximately 2 to 4 meter depth.

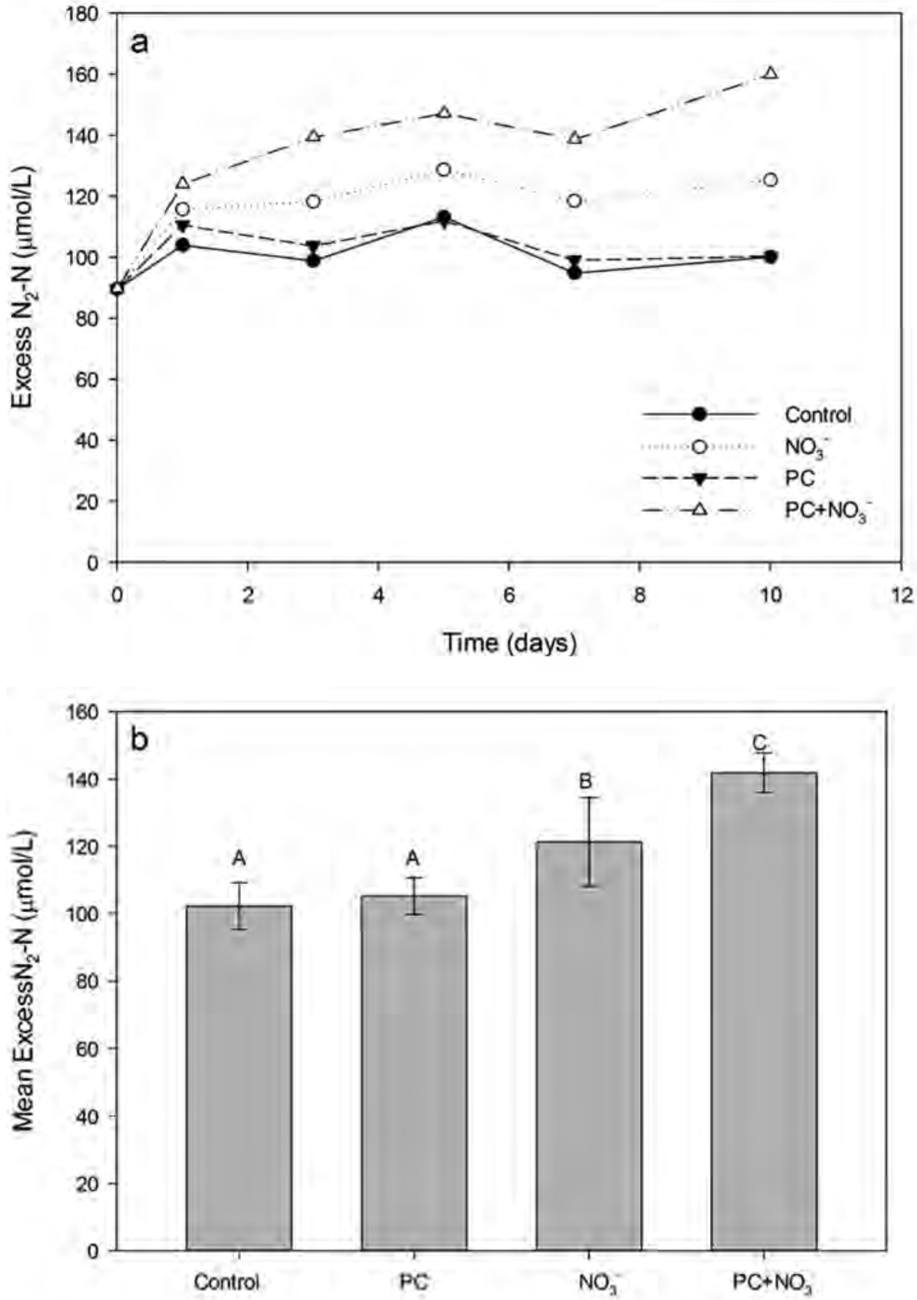

Fig. 2(a) Changes in excess N_2-N concentrations by addition of different combinations of nitrate (NO_3^-) and particulate carbon (PC); **(b)** Mean excess N_2-N concentrations in treatments using different combinations of NO_3^- and PC.

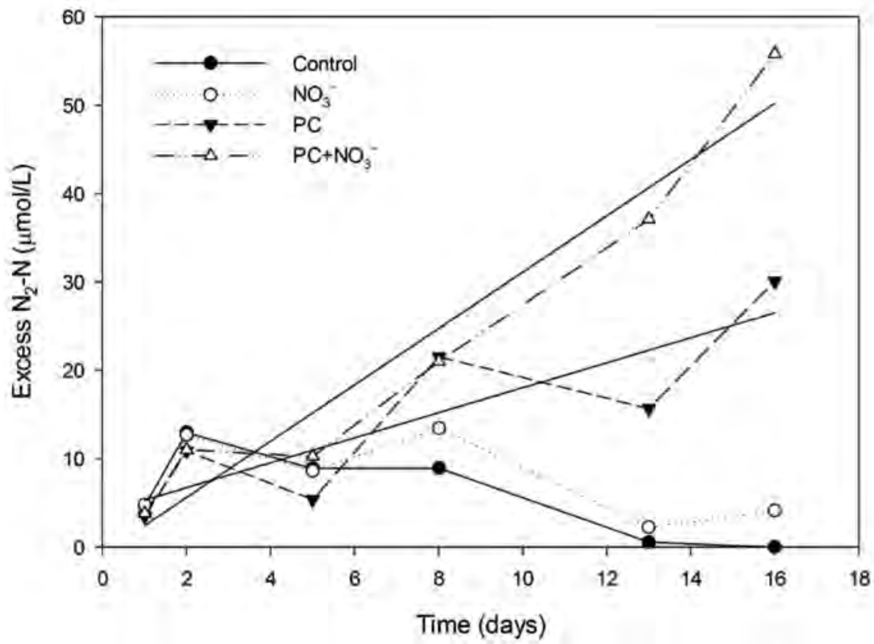

Fig. 3. Changes in excess N_2-N concentrations by different combinations of nitrate (NO_3^-) and particulate carbon (PC) after an aeration event and rates of excess N_2-N concentration increases.

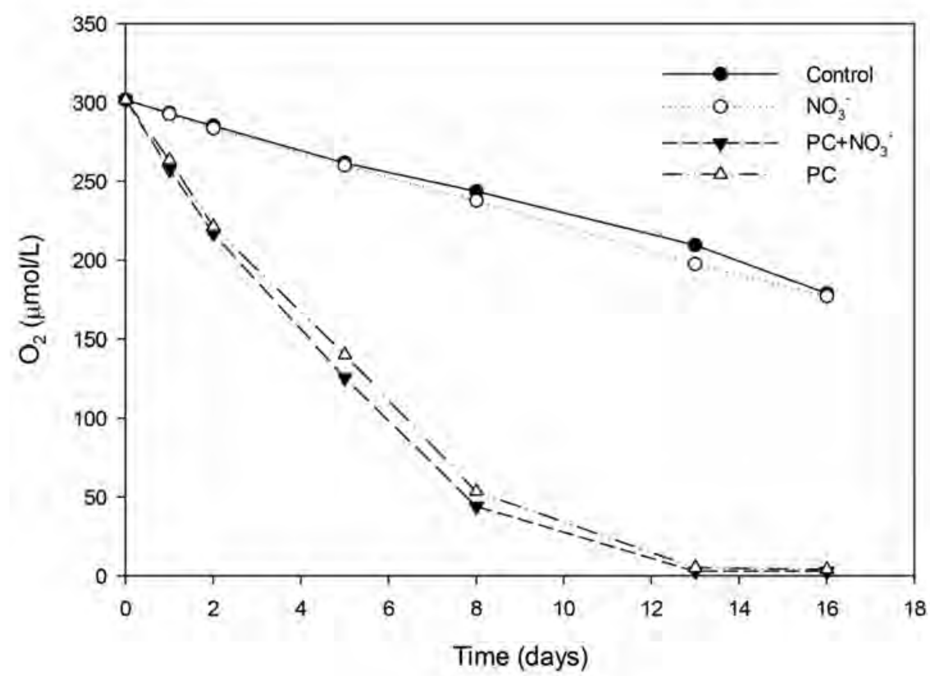

Fig. 4. Changes in excess O_2 concentrations by different combinations of nitrate (NO_3^-) and particulate carbon (PC) after an aeration event.

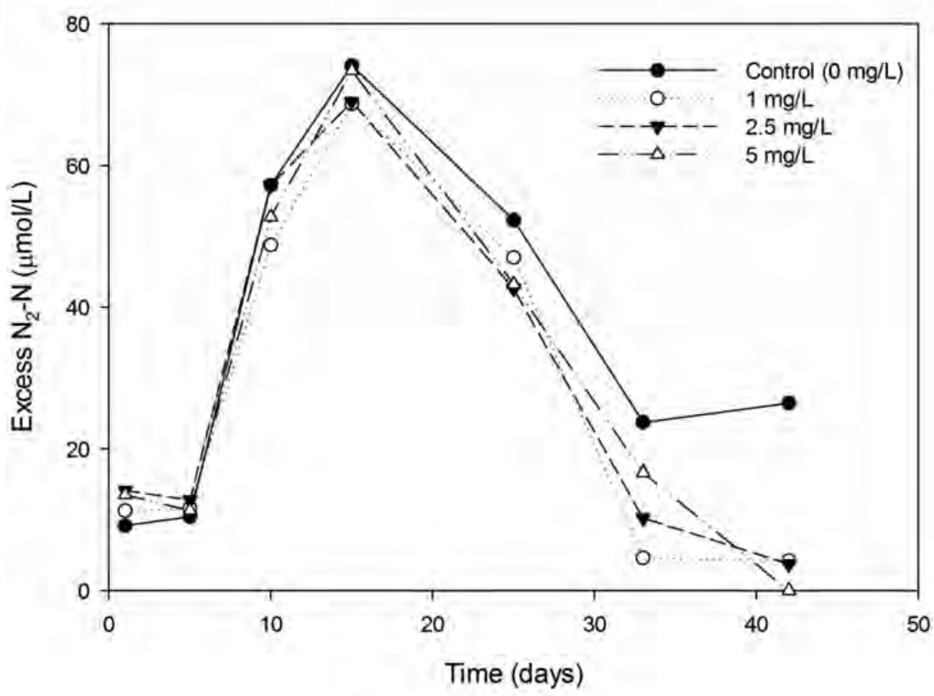

Fig. 5. Changes in excess N_2-N concentrations by addition of particulate carbon and different concentrations of nitrate (NO_3^-) above the background concentration of NO_3^-.

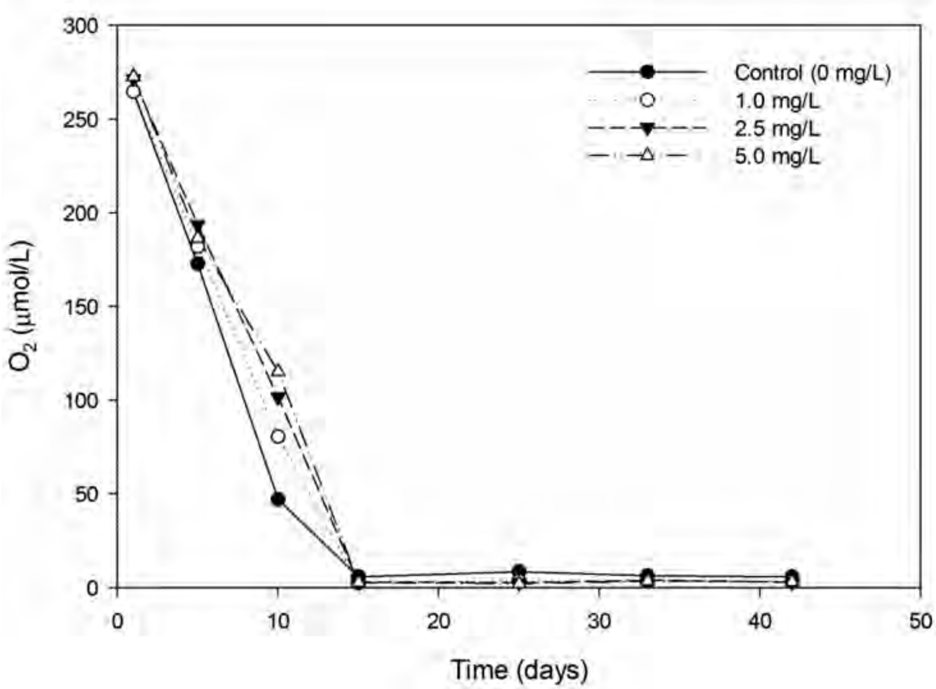

Fig. 6. Changes in excess O_2 concentrations by addition of particulate carbon and different concentrations of nitrate (NO_3^-) above the background concentration of NO_3^-.

The relationship between the first impression that dress creates and college students' reactions toward it

Quang Ngo and Kathleen Smith†*

ABSTRACT

Dress preserves history, embraces traditions, and links different generations together. With the ability to communicate non-verbally, dress conveys a picture or sends a message about its wearer to those who observe the individual. Therefore, dress can create first impressions for the beholders. Previous research reveals that professional dress creates more positive first impressions. The goal of this study was to identify whether college students would react differently to different types of dress and whether specific types of dress would have influences on college students' first impressions of a male or female peer. Results of the study indicated that college students did not form positive first impressions upon looking at professional business dress. They preferred casual and business casual attire, which was supported by their indications that they were more willing to have a conversation with those who were dressed in these styles. Both male and female college students expressed their preferences for casual and business casual clothes. The study reinforced findings of previous studies that dress and first impressions are related.

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MEET THE STUDENT-AUTHOR

Quang Ngo

I was born and raised in Ho Chi Minh City, Vietnam. After my graduation from Tran Dai Nghia high school, I decided to study abroad at the University of Arkansas. I graduated with a Bachelor of Science in Human Environmental Sciences with an emphasis in Apparel Studies and a Bachelor of Arts in French. During Spring and Summer 2012, I studied abroad in Paris, France and then in Prague, Czech Republic. I was the treasurer of the Agricultural, Food and Life Sciences Honors Program Student Board, and a member of Phi Upsilon Omicron National Honor Society. I was accepted to present my honor thesis at the annual Popular Culture Association/American Culture Association (PCA/ACA) conference in Washington, D.C. in March 2013. After completing my internship in Fall 2013, I intend to apply for a Ph.D. program in the United States studying Communications. I would like to do more research on the topic of media, cultures, and dress. I would like to express my deep gratitude toward Dr. Kathleen Smith for her guidance and support. I also appreciate the help from my committee members, Dr. Laurie Apple, Dr. Curt Rom, Dr. Leigh Southward, and Ms. Lorna Harding. Finally, I would like to thank Dr. Duane Wolf and Dr. Nick Anthony who had assisted me to narrow down the topic for my research.

INTRODUCTION

Common knowledge holds that whenever people first meet, they know nothing or very little about each other. Nevertheless, Gille and Mittag (2008) managed to find the relationship between dress and perceptions of intelligence. Comparing conservative (smart) and provocative (sexy) clothing on female students, they suggest that those who dress provocatively are perceived to be less intelligent than those who clothe themselves conservatively. Females who dress conservatively provoke a positive image of intelligence. Nevertheless, dressing provocatively illustrates a higher level of liberalism, openness to sexuality and self-expression (Gille and Mittag, 2008). Research additionally shows that students discern university professors wearing casual or semi-formal attire to be less credible that ones in formal dress (Lightstone et al., 2011).

What exactly are first impressions? They usually refer to the way others perceive an individual for the first time by applying opinions to certain characteristics that the individual possesses. Indeed, the first impression contributes to how a person reacts to another or the types of relationship that will be created between them (Hubbard, 1994). People's dress, or their specific ways of dressing, probably leads others to judge, guess or interpret something about their characteristics (Miller-Spillman et al., 2012).

According to the article "Life: Relationships First Impressions Tell the First 30 Seconds of an Interview Often Determines if You Get Hired or Not" (anonymous, 2012), people have approximately 30 seconds in order to make a good impression on others, meaning that the impression that they create in such brief period of time establishes the opinion of that person. Indeed, books and articles have been published with the purpose of discussing, providing fashion tips or emphasizing dressing to impress others in different occasions.

It is not difficult to notice the increasing significance of dress. Indeed, individuals' dress plays a great part in conveying an impression (whether negative or positive) that influences how others perceive someone. Those who took the survey conducted by TheLadders.com thought that casual dress tended to be unsuited to the workplace; they even believed that others were less likely to consider them professional (Esbenshade, 2011).

Universities across the nation recognize the importance of how their students dress for professional events, leading to the establishment of programs and campaigns that focus on helping their students dress to create a positive image. The Career Closet program from universities such as Kansas State University (http://www.k-state.edu/ces/students/calendar.html), the University of Texas at San Antonio (http://utsa.edu/careercenter/) and the Sam M. Walton College of Business Career Development

Center (http://waltoncollege.uark.edu/career/closet.asp) is a quintessential illustration of such activity. Fundamentally, this program asks for donations of professional attire for students in need to borrow since they solely believe that professional dress can help their students in projecting a positive image towards job recruiters (KSU, UAWC, and UTSA, 2012).

An important component in the research was to identify three different types of dress used in the survey; they included: (1) *business professional dress*: formal, conservative suits for both genders, good grooming, and suitable accessories; these dress codes are usually applied to individuals working in law, finance or public relations; (2) *business casual dress*: well put together ensembles but not a very conservative look when compared to business professional dress; clothing items that belong to this group include sportswear, including slacks or chinos, button-down shirts, collared sport shirts and casual skirts or dresses and (3) *casual dress*: unprofessional and non-conservative clothing items that are worn on a daily basis such as sweatpants, T-shirts, jeans, flip-flops, shorts, sleeveless tops, cut-out jeans, etc. (Magloff, n.d.; BYU, 2012).

This study attempted to examine how far the first impression can affect people's point of view about a person during brief encounters. The purpose was to determine whether college students were willing to have a conversation with someone they have never met before based on how he or she dressed. Being 18 and older, participants were mostly college students of a large, mid-southern, tier-one research institution. Questions about the demographics included gender, major, ethnicity and class levels. Data were collected to determine how college students considered a specific type of dress (business professional, business casual, or casual) to form a positive or negative impression. Results of the study helped determine whether such impressions created by dress influenced college students' willingness to talk to the wearer.

Research questions included: (1) Do college students respond more positively to business professional dress or to casual dress?; (2) Do college students respond more positively to business casual dress or to casual dress?; (3) Do first impressions impact college students' willingness to have a conversation with others based primarily on their dress?; and (4) Do male and female college students form different impressions about the same individuals wearing the same outfits?

MATERIALS AND METHODS

A first impression is subjective because it is based on personal perceptions and preferences. A survey design method was used to determine how people react to another person, with whom they are not familiar, during their first encounter. The survey, which contained 14 multiple-choice questions, was developed and piloted by the researcher prior to being administered. Three different combinations of dress were included in the survey. Each combination, two pictures of the same person with his or her face hidden and wearing different clothes, was used for comparison. This method was to test whether or not the reaction of college students to the same individuals differed based solely on their dress. To avoid bias and distraction from the background, photos were taken in front of white walls. Clothing selected fell into three different categories: business professional, business casual, and casual.

The first combination included the same female wearing casual: t-shirt and short flower-printed dress (Fig. 1a), and business professional: suit jacket and pants dresses (Fig. 1b). The second combination showed another female dressing in casual: t-shirt and jeans (Fig. 1c), and business casual: blouse, jacket and pants (Fig. 1d).

The final combination had the same male dressing in casual: shirt and shorts (Fig. 1e), and business casual: shirt, tie and black pants (Fig. 1f).

Participants were asked to view each combination, to rate each photo on the scale of 1-5 (1 = negative, 2 = somewhat negative, 3 = neutral, 4 = somewhat positive, 5 = positive), and then to decide based on the attire whom they would want to talk to if the person in these photos approached them. Some questions about demographics, including age, gender, ethnicity, major, and class level were included in the survey as well. The survey allowed the researcher to measure the essence of the first impression.

A total of 653 college students, from randomly selected courses, participated in the survey. Surveys were distributed manually in classes by the researcher with professors' consent. Participants, ages 18 and older, came from different departments at the University of Arkansas. Despite being limited to college students who enrolled at a large, tier-one, mid-southern research institute, respondents of the survey made up a representative sample of the population.

Institutional Review Board approval was obtained before surveys were distributed. Data were collected and were then entered into an Excel spreadsheet. Using SPSS software, descriptive statistics were used to analyze data. Analysis of variance (ANOVA) was also applied to age, ethnicity, majors, and class level. Pair sample *t*-test was conducted to determine differences in responses between genders. The statistical significance of the data was set at $P \leq 0.05$.

RESULTS AND DISCUSSION

Out of the 653 participants who completed the survey, 100 were male and 553 were female, resulting in the response rate of 15.3% and 84.7%, respectively (Table 1). Over 81% of the respondents were 18-21 years old; the remaining 19% were over 22 years old. One hundred seventy apparel studies majors (26.3%), 23 business majors (3.5%), 137 hospitality majors (21.0%), 153 other human environmental sciences majors (23.4%), and 168 other university majors (25.7%) were recorded. Data regarding ethnicity indicated that 543 respondents were Caucasian (83.2%) while only 16.8% identified themselves as American Indian/Alaska Native, Asian, African American, Native Hawaiian/Other Pacific Islander, Hispanic/Latino, and other. Results of class level indicated that 15.6% were freshmen, 29.1% were sophomores, 31.4% were juniors, 22.5% were seniors, and 1.4% were graduate students participating in the survey.

Research Question 1: In combination 1, college students were asked to rate two photos of the same female wearing casual dress (t-shirt and short flower-printed dress) (Fig. 1a) or business professional dress (black suit jacket and pants) (Fig. 1b). Nearly 40% of participants had somewhat positive impressions when observing casual dress (Fig. 1a), while approximately 30% had neutral impressions (Table 2). Business professional dress (Fig. 1b) was considered somewhat negatively and neutrally.

Research Question 2: After viewing photos of combination 2 and 3, college students compared casual (Fig. 1c) and business casual dress (Fig. 1d) of a female, and casual (Fig. 1e) and business casual dress (Fig. 1f) of a male. In combination 2, nearly 39% of participants formed neutral impressions when observing the casual dress worn by the female (Fig. 1c) (Table 3). The percentage of college students reacting somewhat positively to business casual dress (Fig. 1d) was approximately 46%. In combination 3, over 37% of respondents said that they had somewhat positive impressions toward the male dressing casually (Fig. 1e; Table 4). Approximately 31% of college students demonstrated that their first impressions toward the male's business casual dress in Fig. 1f were neutral.

Research Question 3: In combination 1, participants were asked whether they would be more willing to talk to the female in casual dress (Fig. 1a) or the one in business casual dress (Fig. 1b). More than 66% of the respondents chose the person in casual dress (Table 5). The result of the paired *t*-test was statistically significant ($P = 0.015$), meaning that college students reacted the same way toward the casual dress. In combination 2, 49% of participants considered that they would talk to both if approached by the female in casual dress (Fig. 1c) and the one in business casual dress (Fig. 1d; Table 5). The paired *t*-test's indication of the result being statistically significant ($P = 0.002$) validated the same reaction that college students of the study had. In combination 3, 48% of respondents indicated that they would like to talk to the male regardless of his casual (Fig. 1e) or business casual dress (Fig. 1f; Table 5). Results of the paired *t*-test of combination 3 were not statistically significant ($P = 0.289$).

Research Question 4: In combination 1, 45.0% of male college students indicated that they had somewhat positive impressions toward the casual dress of the female (Fig. 1a; Table 6). More than 38% of female college students had the same reaction. Nevertheless, when observing business professional dress of the female, male college students had neutral impressions while female participants indicated having neutral and somewhat negative impressions (Table 6). In combination 2, 41% of male college students considered the female's casual dress somewhat positively, while 40% of female college students indicated neutral first impressions (Table ??). Sixty-three percent of males indicated somewhat positive impressions upon observing business casual dress. Female college students formed somewhat positive and neutral first impressions toward the female's business casual dress with 42.7% and 41.8%, respectively (Table 6). In combination 3, 33.0% of male college students looked at the male's casual dress (Fig. 1e) and formed a neutral impression while 38.3% of female participants had a somewhat positive impression. Participants of both genders were neutral in their first impressions of the male's business casual dress (Fig. 1f) with percentages of 31.0% and 30.6%, for males and females, respectively (Table 6).

The project's main purpose was to examine influences of dress on college students in their forming first impressions and in their inclination to start a conversation with strangers. Eighteen to twenty-one-year-old college students made up the biggest portion of participants. Freshmen, sophomores, juniors, seniors and graduate students were able to take part in the study. Majors that contributed to the study came from many different departments at the University of Arkansas. Upon looking at others' dress and clothes, college students of both genders immediately formed first impressions.

Both male and female college students did not react positively to business professional dress. This might be explained by the idea that business professional dress tended to be less friendly than other types of dress. It was possible that formal dress made wearers appear more confident and professional as stated in other studies (Gille et al., 2008; Lightstone et al., 2011; Olguin and Stankus, 2011). Nevertheless, this type of dress was limited to specific types of professions, such as lawyers, politicians, professors, or even librarians that required respect and credibility (Lightstone et al., 2011; Olguin and Stankus, 2011).

Because college students have not entered the workplace yet, they may tend to react more positively to casual dress (t-shirts, jeans, short skirts, and shorts) and dress that does not look so severe and conservative. Therefore, results of the study tended to disconfirm findings that formal and professional dress would allow others to think of the wearer more positively most of the time. This could also explain why many colleges and universities across the nation attempt to set up programs teaching how to dress appropriately prior to entering the workplace.

More than half of college students did not prefer to have a conversation with students who were dressed in business professional clothing. College students' positive impressions toward casual and business casual dress prompted their likelihood to talk to those who wore this type of dress. This would seem to indicate that college students were more comfortable with individuals who were clothed in more nonprofessional attire. Thus, results of the study did not support literature regarding how business professional dress was perceived better than nonprofessional dress (casual and business casual) (Tahmincioglu, 2011; Prescott, 2011). Casual and business casual tended to hold more influence on how willingly college students would start a conversation.

This group of male and female college students tended to share the view that business professional dress was not very well received among them. They considered this type of dress somewhat negatively and neutrally. However, most males and females reacted somewhat positively and neutrally toward casual and business casual dress. Male and female college students did not differentiate about dress and their impressions. This tended to indicate that regardless of gender, college students preferred nonprofessional attire to that of professional attire.

CONCLUSIONS

In this research study, it was demonstrated that college students form first impressions toward others by observing other college students' clothing; such a finding strengthens previous research (Johnson et al., 2002; Miller-Spillman et al., 2012). College students also do not seem to react positively to business professional dress; they instead prefer talking to individuals dressing in more casual and business casual attire. Both genders have similar perceptions toward impressions that these three types of dress create. Results of the study differ from opinions of professional experts who stress wearing business professional attire in job interviews and in the workplace (Tahmincioglu, 2011; Hemmerdinger, 2011). Nevertheless, such results indicate the necessity for colleges and universities across the U.S. to establish programs where their students understand the importance of business professional clothing and how to dress professionally prior to starting their career. This may be a result of college students not understanding how to dress professionally and not being confortable with professional dress. The study should be expanded to individuals who have already entered the workplace in determining whether they would respond to these questions differently. Further research should be conducted to include data from other ethnicities and students from other colleges and universities across the nation. The study also needs to include additional business majors as professional attire may prove more important in other professional fields.

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A
B
C
D

Fig. 1. Combination 1: (a) casual dress; (b) business professional dress. Combination 2: (c) casual dress; (d) business casual dress. Combination 3: (e) casual dress; (f) business casual dress.

Table 1. Participant characteristics.

Demographic variable	Number	Percent
Gender		
Male	100	15.3
Female	553	84.7
Total	653	100
Age		
18-19	251	38.4
20-21	281	43
22-23	63	9.6
Over 24	58	8.9
Total	653	100
Major		
Apparel Studies	172	26.3
Business	23	3.5
Hospitality	137	21
Other Human Environmental Sciences	153	23.4
Other University of Arkansas Majors	168	25.7
Total	653	100
Ethnicity		
American Indian/Alaska Native	9	1.4
Asian	13	2
African American	35	5.4
Native Hawaiian/Pacific Islanders	1	0.2
Caucasian	543	83.2
Hispanic/Latino	29	4.4
Other	23	3.5
Total	653	100
Class Level		
Freshman	102	15.6
Sophomore	190	29.1
Junior	205	31.4
Senior	147	22.5
Graduate	9	1.4
Total	653	100

Table 2. Frequencies for participants' response and dress in Combination 1 (female wearing causal and business professional dress).

Questions	Number	Percent
What is your first impression about the person in Fig. 1a and her dress? (Casual)		
Negative	12	1.8
Somewhat Negative	58	8.9
Neutral	198	30.3
Somewhat Positive	257	39.4
Positive	128	19.6
Total	653	100
What is your first impression about the person in Fig. 1b and her dress? (Business Professional)		
Negative	53	8.1
Somewhat Negative	209	32
Neutral	209	32
Somewhat Positive	127	19.4
Positive	55	8.4
Total	653	100

Table 3. Frequencies for participants' response and dress in Combination 2 (female wearing causal and business casual dress).

Questions		Number	Percent
What is your first impression about the person in Fig. 1c and her dress? (Casual)			
	Negative	26	4
	Somewhat Negative	133	20.4
	Neutral	253	38.7
	Somewhat Positive	167	25.6
	Positive	74	11.3
Total		653	100
What is your first impression about the person in Fig. 1d and her dress? (Business Casual)			
	Negative	3	0.5
	Somewhat Negative	15	2.3
	Neutral	92	14.1
	Somewhat Positive	299	45.8
	Positive	244	37.4
Total		653	100

Table 4. Frequencies for participants' response and dress in Combination 3 (male wearing causal and business casual dress).

Questions		Number	Percent
What is your first impression about the person in Fig. 1e and his dress? (Casual)			
	Negative	16	2.5
	Somewhat Negative	67	10.3
	Neutral	207	31.7
	Somewhat Positive	244	37.4
	Positive	119	18.2
Total		653	100
What is your first impression about the person in Fig. 1f and his dress? (Business Casual)			
	Negative	43	6.6
	Somewhat Negative	136	20.8
	Neutral	200	30.6
	Somewhat Positive	172	26.3
	Positive	102	15.6
Total		653	100

Table 5. Frequencies for each combination.

Combination 1 (female wearing causal and business professional dress). Frequencies for participants' willingness to have conversation based on dress.		
Questions	**Number**	**Percent**
If person in Fig. 1a and person in Fig. 1b approach you, which one would you prefer talking to?		
Person A	432	66.2
Person B	41	6.3
Both	180	27.6
Total	653	100

Combination 2 (female wearing casual and business casual dress). Frequencies for participants' willingness to have conversation based on dress.		
Questions	**Number**	**Percent**
If person in Fig. 1c and person in Fig. 1d approach you, which one would you prefer talking to?		
Person C	50	7.7
Person D	283	43.3
Both	320	49
Total	653	100

Combination 3 (male wearing casual and business casual dress). Frequencies for participants' willingness to have conversation based on dress.		
Questions	**Number**	**Percent**
If person in Fig. 1e and person in Fig. 1f approach you, which one would you prefer talking to?		
Person E	241	36.9
Person F	98	15
Both	314	48.1
Total	653	100

Table 6. Frequencies for comparison between male and female college students' reponses.

	Gender	
	Male (%)	**Female (%)**
Combination 1 (female wearing causal and business professional dress):		
What is your first impression about the person in Fig. 1a and her dress?		
Negative	3.0	1.6
Somewhat Negative	5.0	9.6
Neutral	27.0	30.9
Somewhat Positive	45.0	38.3
Positive	20.0	19.5
Total	100	100
What is your first impression about the person in Fig. 1b and her dress?		
Negative	9.0	8.0
Somewhat Negative	25.0	33.3
Neutral	31.0	32.2
Somewhat Positive	24.0	18.6
Positive	11.0	8.0
Total	100	100
Combination 2 (female wearing casual and business casual dress):		
What is your first impression about the person in Fig. 1c and her dress?		
Negative	1.0	4.5
Somewhat Negative	16.0	21.2
Neutral	31.0	40.1
Somewhat Positive	41.0	22.8
Positive	11.0	11.4
Total	100	100
What is your first impression about the person in Fig. 1d and her dress?		
Negative	0.0	0.5
Somewhat Negative	5.0	1.8
Neutral	19.0	13.2
Somewhat Positive	63.0	42.7
Positive	13.0	41.8
Total	100	100
Combination 3 (male wearing casual and business casual dress):		
What is your first impression about the person in Fig. 1e and his dress?		
Negative	4.0	2.2
Somewhat Negative	17.0	9.0
Neutral	33.0	31.5
Somewhat Positive	32.0	38.3
Positive	14.0	19.0
Total	100	100
What is your first impression about the person in Fig. 1f and his dress?		
Negative	7.0	6.5
Somewhat Negative	21.0	20.8
Neutral	31.0	30.6
Somewhat Positive	28.0	26.0
Positive	13.0	16.1
Total	100	100

Nutrient contents, color, texture, and sensory evaluation of 12 Arkansas grown soybean cultivars in canned products

Quyen T. Nguyen, Navam Hettiarachchy†, and Srinivas J. Rayaprolu§*

ABSTRACT

Soybean was introduced in the U.S. in the 1800s, and it has been proven to have several health benefits. New cultivars of soybeans with varying hull colors have been developed using plant-breeding technology. Canning is one of the effective processing methods to extend the shelf life of products. However, very little information is available on canned soybeans. This research studied the composition of 12 soybean cultivars including two cultivars with brown seed coat (R08-4014 and R09-349), three cultivars with black seed coat (R07-1927, R07-10396, and R09-345), and seven regular cultivars with yellow seed coat (R05-1772, R05-4969, R07-2001, R08-4005, R08-4006, UA Kirksey, and JYC-2) grown in Arkansas and investigated the effect of the canning process on the color, texture, and sensory properties. The data showed that the 12 soybean cultivars had lower moisture content values ranging from 6.7% to 9.1% in comparison to higher levels of moisture (13%) present in commercial lines. The protein content ranged from 40.2% to 51.0% which was higher than the expected approximate content of commercial soy (30-40%). The canning process increased the redness (+a values) of the beans but neither off-flavor nor bitterness was observed in the canned products. Among the soybean cultivars with yellow seed, the canned products of JYC-2 were the most preferred according to sensory panelists. In conclusion, canned products of soybeans can be prepared under optimized conditions to produce a product that is acceptable to consumers.

* Quyen Nguyen was a senior majoring in Food Science while working on this project. She is now a graduate student working towards her M.S. degree. This paper is based on a special problems research conducted by her in the Department of Food Science, University of Arkansas.

† Navam Hettiarachchy is the faculty mentor and a University Professor in the Department of Food Science.

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MEET THE STUDENT-AUTHOR

Quyen T. Nguyen

I am from Vietnam and I came to the United States to start my college career in the Fall of 2008 at Northwest Arkansas Community College. I transferred to the University of Arkansas beginning in the Fall 2009. I have enjoyed my time learning in the Department of Food Science by participating in various activities of the Food Science Club as well as being a member of the Product Development Team and College Bowl Team for many Institute of Food Technologists' Student Association Competitions. I have also had the honor of receiving the Outstanding Senior Student Award in the Department of Food Science.

During my junior year, I joined the protein chemistry laboratory of Dr. Navam S. Hettiarachchy. By working in Dr. Hettiarachchy's lab I have gained valuable experience in conducting food science research. During the summer of 2012, I had the opportunity to conduct undergraduate special problem research under the much appreciated support and guidance of Dr. Navam S. Hettiarachchy and her laboratory team. I graduated with my B.S degree majoring in food science and a minor in agribusiness in December 2012. After graduation, I began working towards my M.S. degree in Food Science under Dr. Hettiarachchy's guidance at the University of Arkansas. In the future, I will pursue my career as a product and process developer. Since I love children, I want to devote my career path in research and development of healthy food to prevent childhood obesity.

I would like to thank Dr. Navam S. Hettiarachchy, who provided tremendous support as my mentor throughout my special problem project, and everyone who is part of the protein chemistry research group in the Department of Food Science for all their guidance and help during this project and their ongoing support for my education.

INTRODUCTION

Soybean (*Glycine max*) has been used as a food ingredient for 5,000 years due to its beneficial nutrients such as proteins, isoflavones, and dietary fiber (Nutraceuticals World, 2010). This subtropical plant was introduced into the United States in the 1800s (Nutraceuticals World, 2010). The U.S. Department of Agriculture has been funding projects to develop and improve cultivars of soybean using genetic selection and hybridization (Marsland, 2000). New cultivars of soybean have higher yields, short crop season, pest and disease resistance, and other enhanced attributes in comparison to ancient Asian cultivars (Marsland, 2000). Approximately half of the worldwide supply of soybeans comes from Midwestern U.S. states (Nutraceuticals World, 2010). Apart from improved nutritional benefits, new cultivars of soybean also differ in their seed coat color with pigmentations including yellow, black, brown, red, or green (Messina, 1999). Despite numerous health benefits, raw soybeans are difficult to consume due to the presence of trypsin inhibitor (Singh, et al., 2008). Hence, heat treatment is used to improve the digestion by inactivating most of the trypsin inhibitor in soybean seeds. Cooking not only enhances the nutritional quality but also reduces the off-flavor of soy products (Mozzoni et al., 2009b). Among numerous processing techniques, canning is considered a safe and economical way to preserve food (USDA Guide 4, 2009). Recently, Mozzoni et al. (2009a) studied the effects of blanching duration and brine composition used in the canning process on the texture, color, and lipoxygenase activity of the final canned soybean product. However, the consumer acceptability of canned soybeans with varying seed coat colors has not been studied. In addition, most studies on soybeans have focused on only a few cultivars but not on comparing the composition of different cultivars of soybean at the same time. Hence, the objectives of this research were to (1) compare the composition of 12 soybean cultivars which were categorized into 3 different colors: yellow, black, and brown; (2) determine the effect of the canning process on the texture and color of the soybeans; and (3) evaluate the sensory qualities of canned products. The results may provide useful information for the soybean industry to choose the most acceptable cultivar for commercial canned soybean.

MATERIALS AND METHODS

Materials. Twelve soybean cultivars, including two brown cultivars (R08-4014 and R09-349), three black cultivars (R07-1927, R07-10396, and R09-345), and seven yellow cultivars (R05-1772, R05-4969, R07-2001, R08-4005, R08-4006, UA Kirksey, and JYC-2) grown in Arkansas were supplied by Dr. Pengyin Chen, Professor in the Department of Crop, Soil, and Environmental Sciences at the University of Arkansas.

Proximate Composition Analysis. All of the 12 cultivars of soybean were ground, passed through a 60-mesh sieve (250-μm), and stored at ambient temperature. Moisture content was determined according to the AACC Official Method [44-19] by weighing 2.0 g sample before and after drying for 2 h in a hot air oven at 135 °C (AACC, 2000). Total mineral content (ash content) was determined according to AACC Official Method [08-03] in which exact weights of ground samples (2 g) were placed in a muffle furnace, preheated to 600 °C, for 2 h (AACC, 2000). Protein content was determined by AACC Method [46-11A] "Improved Kjeldahl Method, Copper Catalyst Modification" (AACC, 2000). Samples were weighed (approximately 0.2 g) to the thousandth of a gram and were transferred to Kjeldahl digestion flasks with the addition of a copper catalyst tablet and 10 mL of 10 N sulfuric acid. The samples were digested at 410 °C for 60 min in a Digestor (Foss Tecator, Hillerød, Denmark) and cooled to ambient temperature in a fume hood. The protein contents of the samples were measured in an automatic Kjeltec™ 2300 Distillation Unit (Foss Tecator, Hillerød, Denmark). Lipid content was determined using AACC Official Method [30-25] in which dried samples were treated with petroleum ether solvent to extract the lipid by Soxhlet extraction (AACC, 2000). After 8 h of extraction, the solvent from flasks was evaporated and crude fat was dried to constant weight at 100 °C and the percentage of the lipid content (by weight) in each sample was calculated. The mineral analysis was conducted at the Central Analytical Laboratory, University of Arkansas, Fayetteville, Ark., using inductively coupled plasma emission spectroscopy.

Canning Process. Dried soybeans (50 ± 1 g) were soaked in tap water at ambient temperature for 12 h (Fig. 1). Immature and defective soybeans were removed. Approximately 120 g of the soaked seeds were weighed, and placed in 130 g of 1% NaCl brine solution. The cans were sealed, and processed in a steam sterilizer at 250 °F (121 °C) by maintaining the pressure at 15 PSI (10.3 MPa) to guarantee the safety of food (USDA Guide 4, 2009). After 10 min, cans were removed and cooled in tap water for 2 min, cooled, and stored at ambient temperature. The details of the canning process are provided in Table 1.

Texture Analysis. The texture of canned soybeans was determined using a Texture Analyzer Model XT2i (Stable Micro Systems, Surrey, UK). Canned navy beans were used for comparison. An incisor knife blade bell lock (TA-45) was used to test the shearing force when passed through a sample. The instrument was calibrated with a load scale of 5 kg. Force-time curves were recorded at a constant rate of 1 mm/s and the average maximum force of ten replications, in Newton, with standard deviation.

Color Analysis. The color of dried and canned soybeans were determined using the 'L*, a*, and b*' Hunter Lab system where, L* axis represents lightness from 0 (absolute black) to 100 (absolute white), a* axis represents either green (-a) or red (+a), and b* axis represents either blue (-b) or yellow (+b), which were measured using a CR 100 Minolta Chroma Meter (Minolta Camera Co., Ltd., Osaka, Japan). The colorimeter was calibrated for L = 93.6, a = 0.6, and b = -2.3 values.

Sensory Evaluation. Eight untrained panelists (graduate students, Department of Food Science, University of Arkansas) participated in tasting the canned soybeans. The soybeans, which were canned the day before, were warmed up in microwave for 1 min before serving. Commercial canned navy beans were used as control for comparison. Panelists rated samples based on the following sensory attributes: color and aroma attributes before tasting the samples, and taste, mouth-feel, texture and saltiness attributes after tasting the samples. The samples were grouped in three different categories based on their color: two brown samples (R08-4014 and R09-349), three black samples (R07-1927, R07-10396, and R09-345), and seven yellow samples (R05-1772, R05-4969, R07-2001, R08-4005, R08-4006, UA Kirksey, and JYC-2). The panelists were also asked to choose the one they preferred most in each group by ranking. The scores of the color, aroma, and taste attributes were recorded on a 7-point hedonic scale where 1 = " dislike very much" and 7 = "like very much" while the mouth-feel, texture, and saltiness attributes were recorded on 5 point JAR (Just About Right) category scale where 1 is a low score and 5 is a high score.

Data Analysis. All tests on chemical composition analyses were run in triplicate for each variety of dried soybeans. The twelve cultivars of soybeans seeds were canned in triplicate. Color analysis was read in five replicates per sample. Texture properties were analyzed in ten replicates. Values are expressed as mean ± standard deviation. Analysis of variance (ANOVA) was run to compare among the 12 cultivars and Student's *t*-test was used to study the significant differences ($P < 0.05$) using JMP software.

RESULTS AND DISCUSSION

Proximate Composition Analysis. The moisture contents of the 12 soybean cultivars ranged between 6.7% and 9.1% (Table 2). The moisture contents of the brown, black and yellow cultivars ranged from 8.1-8.9%, 7.9-9.0%, and 6.7-9.1%, respectively. None of the 12 soybean cultivars had moisture content higher than 13% which is the recommended moisture content for storage for dried soybean (Boge et al., 2009). The advantage of having low moisture content is the stability in chemical and microbial reactions that should not become a problem during storage (Boge et al., 2009). On the dry weight basis, the protein content of defatted samples of the 12 different cultivars ranged from 40.2-51.0%. The total lipid content of all samples varied between 15.0% and 30.5%. Among these samples, R08-4006 had the highest protein content (51.0%) and lowest lipid content (15.0%). Cultivars JYC-2 and R08-4014 had the lowest protein content (40.2% and 41.0 %, respectively). Both R08-4006 and JYC-2 are yellow soybean cultivars. Cultivar UA Kirksey had the highest lipid content (30.5%) with a protein content of 46.5 %. Lee and Cho (2011) indicated that most soybean cultivars contain about 30-40% protein and 21-28% lipid on an average; protein content is higher in many of these cultivars. The lipid content in soybeans is considered highest compared to other beans and legumes, and they are rich in omega-3 fatty acids like α-linolenic acid which help in health promotion (Messina, 1999). Total mineral content of 12 soybean cultivars determined by the ash method varied from 2.1% (R09-349) to 6.5% (R07-1927). The differences observed could be due to variation in cultivars and possibly environmental conditions as well (Wolf et al., 1982).

Texture Analysis. Among the 12 cultivars, the R05-4969 variety was numerically the hardest (6.5 N) after the canning process (Table 3). In contrast, R05-1772, R08-4005, R09-345, and UA Kirksey cultivars were the softest and their textures were comparable with that of Navy beans (control). Compared to the control (canned navy bean with 3.5 N), all the 12 canned soybean samples had numerically higher values (4.1-6.5 N), and statistically significant difference was seen among the cultivars ($P > 0.05$; Table 3). The extent of hardness observed could be due to the species differences. Extending the canning process time may be useful to obtain hardness comparable to that of commercial canned beans.

Color Analysis. Although different values were observed among the 12 cultivars (Fig. 1), the canning process resulted in decreased L* (more luminous) for the brown and yellow soybeans and increased a* (more redness) values for soybeans of all three seed coat colors (Table 4) compared to dried soybeans. Among the black colored cultivars there was no change in the L* values before and after canning. However, numerically the b* values of the seven yellow cultivars (R05-1772, R05-4969, R07-2001, R08-4005, R08-4006, UA Kirksey, and JYC-2) and two brown cultivars (R08-4014 and R09-349) decreased, while the values for b* of three black cultivars (R07-1927, R07-10396, and R09-345) increased. The change in a* values of all samples during the canning process was due to the degradation of green hue of soybeans due to their exposure to hot water (Song et al., 2003).

Sensory Evaluation. The color, aroma (before tasting) and the taste, mouth-feel, texture, and saltiness of canned products of 12 soybean cultivars were investigated by sensory evaluation. Among these sensory qualities, the saltiness score of the samples were relatively the lowest and there was no significant difference among the twelve soybean cultivars (score 2.4-3.0 and $P > 0.05$, Table 5). This implied that the concentration of 1% of NaCl in the brine solution used in the canning process was not enough for an acceptable saltiness. The color of all samples had acceptable scores betwen 3.6 and 5.3. However, there was no statistically significant difference within each group of the same color and also among the 12 cultivars (Table 5). The aroma and taste scores of the 12 samples were also high (scores 3.8-5.4 and 3.4-5.0, respectively) and no statistically significant differences were observed among the 12 samples ($P < 0.05$).

Based on the feedback from all the panelists, the aroma of all 12 canned products was acceptable. In addition, there was neither bitterness nor off-flavor (data not shown). An acceptable 'beany' flavor was reported by all panelists (data not shown). The mouth-feel and texture scores of the samples were within the range of 3.1-4.0 and there was no significant difference among the 12 cultivars ($P < 0.05$). The panelists were also asked to choose the most preferred soybean in each group of samples which were distinguished by color: yellow, black, and brown. There was significant difference among the seven yellow soybean cultivars ($P > 0.05$), and JYC-2 was the most preferred sample according to the panelists (data not shown). There was no significant difference among the 3 brown soybean cultivars ($P < 0.05$) where both R07-10396 and R09-345 had same high score as the R07-1927 cultivar. Also, between the 2 black soybean cultivars, there was no statistically significant difference ($P > 0.05$) in preference.

CONCLUSION

The proximate compositions of the 12 soybean cultivars in this study had no statistically significant difference. However, most of these cultivars had higher content of protein (40.2%-51.0%) in comparison to that in commodity soybeans (30-40%). The R08-4006 cultivar had a high protein content of 51.0% and UA Kirksey had high lipid content of 30.5%. The canning process increased the redness (+a values) of the beans. No off-flavor or bitterness was detected in the 12 canned products. Among the 12 soybean cultivars, the canned JYC-2 soybean seeds were the most preferred by the sensory panelists.

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Table 1. Summary of canning process.

Processing conditions	Canning technique
Mass of dried sample (g/can)	50 ± 1.0
Mass of soaked sample (g/can)	120 ± 1.0
Net weight of can (g/can)	250 ± 1.0
Soaking time	12 hour in cool water at room temperature
Can size	65 mm diameter x 80 mm height
Brine solution	NaCl soluion (10g kg^{-1})
Headspace	8 mm
Thermal process	10 min at constant 15 PSI

Table 2. Proximate compositions of 12 dried soybean cultivars.[†]

Soybean cultivars	Moisture content (%)[‡]	Protein (%)[§]	Lipid (%)[§]	Carbohydrate (%)[¶]	Ashing (%)[‡]
Yellow seed coat cultivars					
R05-1772	8.4 ± 0.5^{abc}	48.0 ± 0.4^{b}	17.8 ± 1.0^{fg}	25.8	4.9 ± 0.4^{cde}
R05-4969	8.4 ± 0.4^{abc}	43.0 ± 0.2^{g}	25.1 ± 0.6^{bc}	23.5	4.5 ± 0.5^{de}
R07-2001	9.1 ± 0.4^{a}	42.3 ± 0.1^{h}	26.5 ± 3.7^{b}	22.1	5.8 ± 0.0^{abc}
R08-4005	8.6 ± 1.5^{abc}	44.3 ± 0.3^{f}	24.3 ± 0.7^{bcd}	22.8	6.0 ± 0.0^{ab}
R08-4006	8.7 ± 0.2^{abc}	51.0 ± 0.2^{a}	15.0 ± 1.1^{g}	25.3	5.4 ± 0.0^{bc}
UA Kirksey	6.7 ± 0.1^{e}	46.5 ± 0.5^{c}	30.5 ± 4.1^{a}	16.3	4.1 ± 0.1^{e}
JYC-2	7.1 ± 0.2^{de}	40.2 ± 0.6^{i}	23.2 ± 1.8^{bcde}	29.5	4.2 ± 0.2^{e}
Brown seed coat cultivars					
R07-1927	8.4 ± 0.1^{abc}	43.0 ± 0.2^{g}	23.8 ± 3.2^{bcd}	24.8	6.5 ± 0.1^{a}
R07-10396	9.0 ± 0.3^{a}	45.4 ± 0.0^{e}	20.0 ± 0.5^{ef}	25.6	6.0 ± 0.1^{ab}
R09-345	7.9 ± 0.1^{cd}	47.1 ± 0.2^{d}	21.0 ± 0.4^{def}	24.0	3.1 ± 1.8^{f}
Black seed coat cultivars					
R08-4014	8.9 ± 0.4^{ab}	41.0 ± 0.2^{i}	15.3 ± 0.4^{g}	34.8	5.2 ± 0.0^{bcd}
R09-349	8.1 ± 0.2^{bc}	40.6 ± 0.2^{h}	22.2 ± 0.8^{cde}	29.1	^{g}

[†] Mean of triplicate measurements ± standard deviation. Similar letters within the same column indicate no significant difference ($P < 0.05$).
[‡] Reported on an as-is basis.
[§] Reported on a dry basis.
[¶] Calculated by difference.

Table 3. Textural properties of 12 soybean cultivars' canned products.[†]

Soybean cultivars	Texture of canned bean (N)[‡]
Yellow seed coat cultivars	
R05-1772	4.1 ± 1.4^{bc}
R05-4969	6.5 ± 1.9^{a}
R07-2001	5.0 ± 2.4^{ab}
R08-4005	4.5 ± 2.8^{bc}
R08-4006	4.9 ± 3.1^{ab}
UA Kirksey	4.1 ± 2.5^{bc}
JYC-2	5.2 ± 3.4^{ab}
Brown seed coat cultivars	
R07-1927	5.8 ± 2.2^{ab}
R07-10396	5.0 ± 2.0^{ab}
R09-345	4.4 ± 2.5^{bc}
Black seed coat cultivars	
R08-4014	4.6 ± 4.2^{ab}
R09-349	5.0 ± 1.7^{ab}
Navy bean (control)	3.5 ± 3.1^{c}

[†] Mean of quintuplicate measurements ± standard deviation.
[‡] Texture of samples as, as maximum force in Newton. Similar letters indicate no significant difference ($P < 0.05$).

Table 4. Color properties of 12 dried soybean cultivars and their canned products as measured by a chroma meter.†

Soybean cultivars	Dried samples			Canned samples		
	$L^{*‡}$	a^*	b^*	$L^{*‡}$	a^*	b^*
Yellow seed coat cultivars						
R05-1772	62.0 ± 1.9^{a}	0.0 ± 0.3^{c}	20.9 ± 1.6^{bcd}	52.7 ± 3.8^{bcd}	3.9 ± 0.7^{cd}	16.0 ± 1.6^{abc}
R05-4969	59.4 ± 3.0^{b}	-0.2 ± 0.4^{c}	23.5 ± 2.8^{ab}	49.4 ± 2.8^{d}	2.3 ± 0.1^{fg}	13.5 ± 1.4^{cd}
R07-2001	61.7 ± 2.2^{a}	0.5 ± 0.5^{c}	19.9 ± 2.4^{cd}	56.4 ± 2.5^{a}	4.9 ± 0.6^{b}	17.5 ± 0.5^{a}
R08-4005	54.9 ± 1.6^{d}	0.1 ± 0.3^{c}	19.0 ± 1.9^{d}	54.2 ± 2.5^{ab}	3.1 ± 0.6^{def}	16.6 ± 1.4^{ab}
R08-4006	61.3 ± 0.9^{ab}	-0.2 ± 0.8^{c}	25.3 ± 2.3^{a}	53.0 ± 3.3^{abc}	2.9 ± 0.3^{ef}	15.9 ± 2.0^{abc}
UA Kirksey	60.7 ± 1.0^{ab}	-0.2 ± 0.4^{c}	22.0 ± 2.0^{bc}	52.0 ± 2.6^{bcd}	2.9 ± 0.7^{ef}	14.5 ± 1.3^{bcd}
JYC-2	57.4 ± 1.1^{c}	-2.8 ± 0.9^{d}	21.2 ± 1.2^{bcd}	50.6 ± 3.9^{cd}	1.9 ± 0.6^{g}	16.1 ± 3.0^{ab}
Brown seed coat cultivars						
R07-1927	32.2 ± 1.4^{g}	0.3 ± 0.2^{c}	-0.1 ± 0.1^{g}	32.9 ± 2.3^{g}	3.4 ± 0.7^{de}	2.1 ± 0.3^{f}
R07-10396	31.0 ± 0.9^{g}	0.4 ± 0.3^{c}	-0.3 ± 0.3^{g}	34.3 ± 2.4^{fg}	4.5 ± 1.2^{bc}	3.4 ± 1.1^{f}
R09-345	32.3 ± 1.3^{g}	0.5 ± 0.2^{c}	0.0 ± 0.2^{g}	33.1 ± 0.7^{fg}	4.0 ± 0.4^{bcd}	2.8 ± 0.5^{f}
Black seed coat cultivars						
R08-4014	41.4 ± 1.9^{f}	5.3 ± 1.3^{b}	9.9 ± 3.5^{f}	36.5 ± 1.9^{f}	8.2 ± 0.6^{a}	7.6 ± 1.6^{e}
R09-349	45.4 ± 0.6^{e}	7.0 ± 1.3^{a}	14.6 ± 2.8^{e}	40.4 ± 1.2^{e}	7.6 ± 1.0^{a}	13.0 ± 4.3^{d}

† Mean of quintuplicate measurements ± standard deviation. Similar letters within the same column indicate no significant difference ($P < 0.05$).

‡ L^* value describes the lightness of a product with values ranging from 0 (black) to 100 (white); a^* value describes the color of a product, ranging from red (positive values) to green (negative values); and b^* value describes the color of a product, ranging from yellow (positive values) to blue (negative values).

Table 5. Sensory qualities of canned products of 12 soybean cultivars.†

Soybean cultivars	Before eating		After eating			
	Color	Aroma	Taste	Mouthfeel	Texture	Saltiness
Yellow seed coat cultivars						
R05-1772	4.9 ± 1.1^{a}	4.9 ± 0.8^{a}	4.9 ± 1.1^{a}	3.1 ± 0.4^{a}	3.1 ± 0.4^{a}	2.8 ± 0.7^{a}
R05-4969	5.1 ± 1.4^{a}	4.6 ± 1.1^{a}	4.1 ± 1.0^{a}	3.3 ± 0.7^{a}	3.5 ± 0.8^{a}	2.9 ± 0.6^{a}
R07-2001	5.0 ± 1.2^{a}	4.5 ± 0.9^{a}	4.1 ± 1.3^{a}	3.5 ± 0.5^{a}	3.6 ± 0.5^{a}	2.9 ± 0.8^{a}
R08-4005	4.6 ± 0.9^{a}	4.5 ± 1.3^{a}	4.3 ± 1.4^{a}	3.3 ± 0.9^{a}	3.3 ± 0.7^{a}	2.9 ± 0.6^{a}
R08-4006	4.6 ± 1.3^{a}	4.1 ± 0.6^{a}	4.0 ± 1.1^{a}	3.1 ± 0.6^{a}	3.3 ± 0.7^{a}	2.8 ± 0.7^{a}
UA Kirksey	5.0 ± 1.3^{a}	4.5 ± 1.4^{a}	4.4 ± 1.5^{a}	3.3 ± 0.5^{a}	3.1 ± 0.4^{a}	3.0 ± 0.8^{a}
JYC-2	4.9 ± 1.6^{a}	5.4 ± 1.3^{a}	5.0 ± 1.9^{a}	3.1 ± 0.4^{a}	3.3 ± 0.7^{a}	2.8 ± 0.5^{a}
Brown seed coat cultivars						
R07-1927	3.6 ± 1.3^{a}	4.5 ± 1.4^{a}	4.4 ± 1.8^{a}	4.0 ± 0.8^{a}	4.0 ± 0.5^{a}	2.9 ± 0.6^{a}
R07-10396	4.4 ± 1.5^{a}	4.0 ± 0.9^{a}	4.3 ± 1.3^{a}	3.6 ± 0.7^{a}	3.6 ± 0.7^{a}	2.9 ± 0.6^{a}
R09-345	4.0 ± 1.4^{a}	3.8 ± 1.4^{a}	3.4 ± 0.7^{a}	3.9 ± 0.6^{a}	3.8 ± 0.7^{a}	2.8 ± 0.7^{a}
Black seed coat cultivars						
R08-4014	5.3 ± 1.0^{a}	5.0 ± 0.9^{a}	4.8 ± 1.3^{a}	3.5 ± 0.8^{a}	3.5 ± 0.5^{a}	2.8 ± 0.5^{a}
R09-349	5.1 ± 0.8^{a}	4.3 ± 1.6^{a}	3.4 ± 0.7^{a}	3.3 ± 0.5^{a}	3.5 ± 0.5^{a}	2.4 ± 0.5^{a}

† Mean of score graded by 8 panelists ± standard deviation. Similar letters within the same column indicate no significant difference.

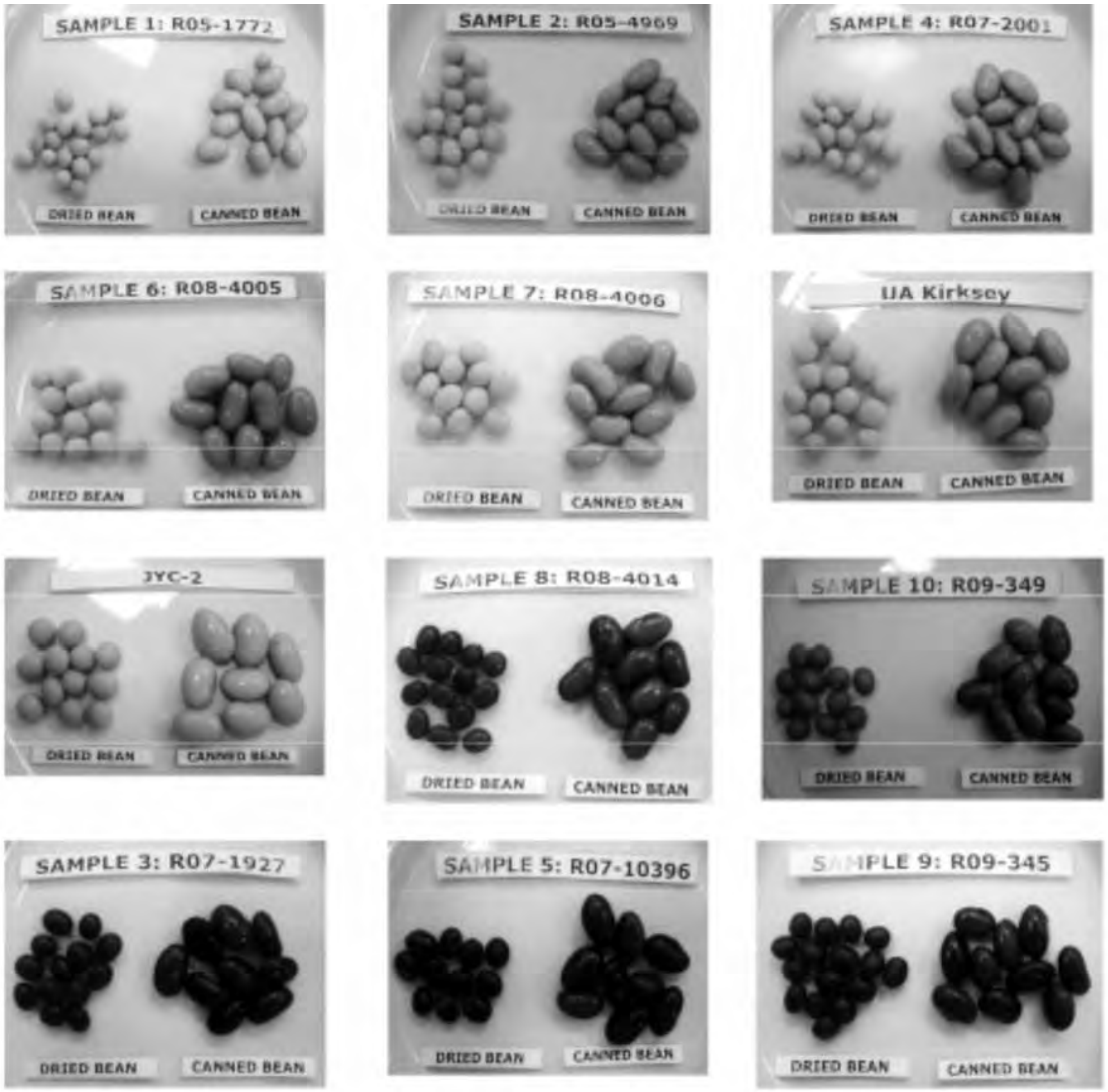

Fig. 1. Twelve dried soybean cultivars and their canned products.

Evaluation of cover crops in high tunnel vegetable rotation

Tyler A. Patrick, Neal Mays†, Jason McAfee§ and Curt R. Rom‡*

ABSTRACT

Organic vegetable production within high tunnels allows for an extended growing season, crop protection, and environmental control. The USDA National Organic Program (NOP) standards mandate evidence that the soil has been maintained and improved over the course of production. Previous studies have indicated the potential of cover crops for reducing competitive vegetation, and improving soil quality, thus resulting in greater plant growth, nutrient uptake, and yield. However, there has been limited work in the confines of high tunnels as part of a tunnel-system rotation. Ten nitrogen-fixing and ten non-legume cover crops were established under a high tunnel and evaluated for their effects on the yield of 'De Cicco' broccoli (*Brassica oleracea* L. var. *italica*) and 'Champion' collards (*Brassica oleracea* L. var. *acephala*), aboveground biomass, and plant C and N contents. All treatments received recommended levels of appropriate certified organic fertilizers, water status was maintained, and vegetables received standard organic maintenance for insects and disease. The cover crops hairy indigo (*Indigofera hirsuta* L.), Catjang cowpea (*Viana unguicalata* L.), and Sunn hemp (*Crotalaria juncea* L.) consistently produced higher yields than Tifleaf III hybrid pearl millet (*Pennisetum glaucum* L.), Dairymaster brown midrib (BMR) hybrid grain sorghum (*Sorghum* spp.), and Wild Game Food sorghum (*Sorghum bicolor* L.). Nitrogen-fixing legumes produced horticulturally significantly higher yields than the non-nitrogen-fixing grass species. This experiment demonstrated that not all cover crops are equal; they created variation in response. Cover crops provide a viable option for organic producers to maintain or improve soil quality over the course of production.

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‡ Curt R. Rom is the faculuty mentor and a Professor in the Department of Horticulture.

MEET THE STUDENT-AUTHOR

Tyler A. Patrick

I am from Harrison, Arkansas, and I graduated from Harrison High School in 2008. I graduated in May 2013 with a B.S. of Horticulture, Landscape, and Turf Science, a minor in Environmental Science, and a minor in Wildlife Management. My passion for horticulture comes from my desire to aid in the development of a more sustainable tomorrow. Growing up on a farm in Arkansas opened my eyes to the difficulties of growing quality crops in the transition zone from warm to cool season crops. My desire was to conduct research measuring the sustainability of high tunnel production in Arkansas vegetable production. During my academic career at the University of Arkansas, I have held various officer positions in Horticulture club and GroGreen campus community garden and conducted an undergraduate research project.

I would like to thank Dr. Curt Rom for his extensive help and guidance through my undergraduate research project. With the additional assistance from Jason McAfee, Neil Mays, Heather Frederick, and Spencer Fiser, I received awards from American Society for Horticultural Science and Gamma Sigma Delta Honors society for my undergraduate research project. The experience conducting a research project, and presenting the results will prove to be a useful experience to overcome future challenges.

INTRODUCTION

The rate of plant growth, yield, and health is closely related to the environment and soil quality in which a crop is cultured. High tunnels (minimally structured, temporary greenhouse-like structures), offer the opportunity for management and control of both the environment and soil quality. The majority of high tunnels contain a hoop-like structure covered by greenhouse-grade plastic, use side curtains for passive ventilation, and are sited on soil. Greenhouse-grade plastics may include polyethylene film, spunbonded polyester and spunbonded polypropylene (Wells, 1996). Other materials used to modify the internal environment include co-extruded copolymer resin tri-layer film, overwintering white film, PVC vinyl, and shade cloth. High tunnels may be constructed to be semi-permanent, movable, or temporary. Despite having been invented in the United States (Emmert, 1955), high tunnel production has just recently gained popularity among specialty crop producers in the U.S.

The extended growing season in high tunnels allows for production during the dormant stage of insect and disease cycles. However, they may increase the rate of soil organic matter (SOM) and plant available nutrient depletion during the growing season. Certified organic producers must follow the USDA National Organic Program (NOP) standards that specify how physical, chemical, and biological conditions of the soil must be maintained or improved. The soil cannot be contaminated with chemicals or compounds such as heavy metals or disallowed pesticide residues (NOP §205.203a; NOP §205.203c; USDA, 2011). Research is necessary to provide organic vegetable producers in high tunnels with alternative soil management practices supported by experimental data. Healthy soil should allow farmers to produce greater plant biomass and yield.

Recent increase in public desire for organic, sustainable, or "naturally" produced food has increased the demand for sustainable soil management. Cover crops are plants grown between cropping cycles for the purpose of improving soil quality and health. Often they are called "green manures". Cover crops can contribute to a more sustainable soil fertility status by improving soil structure characteristics including aggregation, porosity, bulk density, and permeability (Rogers and Giddens, 1957).

Legumes, grasses, and non-legume broadleaf's are the three primary types of cover crops (Verhallen et al., 2003). This experiment focused on legumes and grasses as the two main categories of cover crops for high tunnel vegetable rotations. Legumes have the unique ability to fix atmospheric nitrogen into plant available ammonia. Nitrogen fixation occurs through a symbiotic relationship between legumes and *Rhizobium* bacteria. This process of symbiotic nitrogen fixation is the major naturally occurring mechanism by which nitrogen is introduced into soil, and the ecological and agricultural importance of this process has provided incentive to study this plant-microbe relationship (Franssen et al., 1992).

Nitrogen fixation does not occur in grass crops, which require nitrogen to be present as ammonium, or nitrate in the soil. Grasses are grown as cover crops for their ability to produce large amounts of biomass and suppress competitive vegetation. Some grasses contain allelopathic properties that can inhibit growth of competitive vegetation. Sorghum has particularly high allelopathic properties from root exudation and stem residual biomass (Cheema et al., 2007). Weed control can range as high as 75% for sorghum cover crops (Urbano et al., 2006). An evaluation of nitrogen-fixing legumes and non-nitrogen-fixing cover crop species in vegetable rotation will determine if vegetable yields show variation in response to different types of cover crops.

MATERIALS AND METHODS

This experiment was conducted in the organic block at the University of Arkansas Agricultural Research and Extension Center in Fayetteville, Arkansas. The site is located on a Captina silt loam soil. The soil was amended with poultry litter at the rate of 2.24 Mg/ha in early March, 2011, and seedbeds were prepared using a power takeoff (PTO) driven rototiller prior to planting. The experimental design was a randomized complete block with three replications in a 42.6 m × 6.1 m Quonset style high tunnel. Each replication was grown in a 3.0 m × 1.0 m plot that was seeded at a rate of 74 grams per plot using a 0.9-m Gandy drop seeder.

The ten nitrogen-fixing cover crops include alyceclover (*Alysicarpus ovalifolius* (Schumach.), partridge pea (*Chamaecrista fasciculata* (Michx.), sunn hemp (*Crotalaria juncea* L.), quail haven soybean (*Glycine max* L.), Kester's Bobwhite trailing soybean, Hutcheson soybean, hairy indigo (*Indigofera hirsuta* L.), rongai lablab (*Lablab purpureus* L.), sainfoin (*Onobrychis viciifolia* Scop.), and catjang cowpea (*Viana unguicalata* L.). Non-legume cover crops included mancan buckwheat (*Fagopyrum esculentum* Moench), Tifleaf III hybrid pearl millet (*Pennisetum glaucum* L.), Dove proso millet (*Panicum miliaceum* L.), Japanese millet, (*Echinochloa esculenta,* A Braun), piper sudangrass (*Sorghum vulgare Pers.*), Dairymaster brown midrib (BMR) hybrid grain sorghum (*Sorghum* spp.), Egyptian wheat sorghum, Wild Game Food sorghum, Hegari sorghum, and Sugargrazer II sorghum sudangrass. Cover crops were planted on 7 July 2011. Irrigation was provided using hand-line sprinklers for three weeks after planting. After the initial establishment the cover crops received no further irrigation throughout the summer.

Cover crops were allowed to grow in the high tunnel from early July to mid-August. Non-legume cover crop species had begun to produce seed by mid-August, and all grasses were mowed to a height of 30 cm using a string trimmer. Legumes were not cut but were allowed to go dormant, flower, set seed, and then cut using hand shears. After all of the cover crops were cut down, each plot received three passes using a walk behind sickle mower on 12 January 2012 to reduce the aggregate size of the cover crop debris and aid in decomposition. The crop debris was incorporated into the soil 30 January with a PTO driven rototiller to a depth of approximately 10 cm. To prevent contamination between plots, the plant debris was removed from the tines before proceeding to the next plot. Plots then received a light watering with lawn sprinklers and the high tunnel was completely enclosed to increase soil and air temperature for 30 days.

Organic 'De Cicco' Broccoli (*Brassica oleracea* var. *italica*) and 'Champion' Collards (*Brassica oleracea* var. *acephala*) seed was started in 5.7 cm × 6 cm × 8.25 cm 6-cell packs in a greenhouse 12 February and grown for 25 days before planting into the high tunnel. Each plot received 2.27 kg of Bradford Organics™ Luscious Lawn and Garden 3-1-5 fertilizer, which was incorporated using a PTO driven rototiller at the beginning of March. The plots were then covered with landscape fabric to prevent competitive vegetation prior to planting. Three broccoli plants were planted in each plot in a straight line, spaced approximately 0.5 m apart, on the inside half of the plots, and six collards oriented in two staggered rows of three were planted in the outside half of the plots.

Cutworms (*Agrotis* spp.) were observed in the high tunnel in mid-March causing minor damage to the broccoli and collards. Javelin® WG, an organically certified *bacillus thuringiensis* (BT) pesticide, was applied with a SCHURflo® backpack sprayer on 30 March, at a rate of 0.448 fg/ha. Cabbage loopers [*Trichoplusia ni* (Hübner)] emerged the first, third, and fourth week of April causing damage to the broccoli and collard leaves. Javelin® WG was applied a second time at the rate of 0.18 kg/acre on 9 April and once again on 20 April with SHURflo® backpack sprayer. Deliver™, a more potent BT insecticide, was applied 30 April at the rate of 0.448 kg/ha.

Each vegetable crop received two harvests during the 2012 production season. Collard leaves were collected and weighed as individual plots on 20 April and 6 May. The broccoli was harvested and weighed on 5 and 16 May. After the last harvest, leaf samples were collected from each plant, and plant biomass was recorded. Cover crops were ranked from 1 to 20 with 1 representing the highest total broccoli and collard yields. The broccoli and collard scores were then added together to create an overall cover crop ranking (Table 1). Carbon and nitrogen concentration and content was determined from leaf samples collected after the final harvest 16 May 2012 for both crops. Leaf tissue from each test crop per plot was forced-air dried at approximately 50 °C for 2 weeks and ground into a fine powder using a rotating-blade coffee grinder. Approximately 10 mg (+/- 0.3 mg) of each leaf sample was loaded into tin boats and placed in an Elementar vario EL cube (Elementar Americas, Inc., Philadelphia, Pa.) for analysis of total % C and % N by incinerating the samples at high temperature combustion at approximately 1200 °C. Total leaf % C and % N concentrations were obtained for the leaf samples in each treatment plot as derived by Elementar software, and all were expressed as mg/kg on a dry weight basis. Statistical Analysis Software (SAS) using least significant difference (LSD) was used to analyze test crop yield, total plant biomass, and leaf sample % C and % N.

RESULTS AND DISCUSSION

All cover crops in a high tunnel vegetable production rotation were not equal; different cover crop species created variation in vegetable crop response. Data were collected on broccoli and collard total yield, average yield per plant, plant biomass, and % C and % N (Tables 1 and 2) and treatments resulted in no statistical differences. Despite the lack of statistical differences, the vegetable yield data showed horticultural significance. The yield of 'De Cicco' Broccoli (*Brassica oleracea* var. *italica*) and 'Champion' Collard (*Brassica oleracea* var. *acephala*) was affected by the cover crops that preceded them in rotation (Table 3). Broccoli demonstrated greater variation in response to the different cover crop treatments; this could be due to differences in growth habit and nutrient requirements between broccoli and collard greens. The cover crops hairy indigo (*Indigofera hirsuta* L.), catjang cowpea (*Viana unguicalata* L.), and sunn hemp (*Crotalaria juncea* L.) ranked as the top three overall cover crops (Table 3). Tifleaf III hybrid pearl millet (*Pennisetum glaucum* L.), Dairymaster (BMR) hybrid grain sorghum (*Sorghum* spp.), and Wild Game Food sorghum (*Sorghum bicolor* L.) ranked as the bottom three cover crops based on a combined broccoli and collard overall ranking scale. Four out of the top five cover crops were nitrogen fixing, and six out of the top ten cover crops were nitrogen fixing.

No statistically significant variation among the treatments was observed; however the broccoli yields did show differences that may have horticultural significance. Horticulturally important variation in total yield, average yield per plant, plant biomass, and % C and % N (Tables 1 and 2) was observable. Sainfoin (*Onobrychis viciifolia* Scop.), Sugargrazer II sorghum sudangrass (*Sorghum* spp.), quail haven soybean (*Glycine max* L.), mancan buckwheat (*Fagopyrum esculentum* Moench), Dairymaster (BMR) hybrid grain sorghum (*Sorghum* spp.), rongai lablab (*Lablab purpureus* L.), and Tifleaf III hybrid pearl millet (*Pennisetum glaucum* L.) produced less than 50% of the highest achieved total broccoli yield produced though harvest from hairy indigo (*Indigofera hirsuta* L.) (Table 1). Broccoli and collards exhibited similar performance when comparing legume and non-legume cover crops (Table 3). Both test crops had marginally better results when preceded by legume cover crops. Four out of the top five ranking cover crops for collards were nitrogen-fixing crops (Table 3). On average, the nitrogen fixing cover crops ranked higher than the non-nitrogen fixing cover crops. Although there were no significant differences due to treatments, there were slight increases in broccoli yield (14%), average yield per plant (22%), biomass (8%), and %N (11%) of plants grown after a legume compared to those following non-legumes. There was no significant relationship between foliar N content and either broccoli yield or average yield per harvest. Total broccoli biomass was significantly related to increased leaf N although with a small relationship ($r^2 = 0.34$). Collards planted after legumes had 12% greater harvested yield, 13% greater average yield, 4% greater residual biomass and 4% greater foliar N. Both total yield and average yield were related to foliar N content ($r^2 = 0.47$, and 0.31, respectively). These data provide some evidence that leguminous crops which fix N symbiotically may provide a residual or supplemental source of N to enhance subsequent crop growth. No soil test was conducted to determine the soil-available N after the cover crops. Conversely, the microbial decomposition of nonlegumes may have resulted in sequestered-N that was not available for crop growth although this premise was not tested. It is well documented that increased available N can enhance plant growth and cropping, while limited available N may limit growth and cropping.

Continued research on cover crops incorporated into high tunnel vegetable rotations may provide a viable alternative soil management plans to help maintain or improve the soil over years of production. However, further research is needed to find the most appropriate cover crop or cover crop mix for high tunnel vegetable production. The next steps of research should focus on how cover crops affect competitive vegetation, and the need for soil amendments, nutrient cycling, and water management. Future research on the subject should make amendments to the experimental design, create more replications of each cover crop treatment, and increase the plot size.

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Table 1. Broccoli test crop total yield, average yield per plant, plant biomass, % N, and % C for each cover crop treatment.

Treatment[a]	Total Yield (g)	Average Yield/ Plant (g)	Plant Biomass (g)	Nitrogen (%)	Carbon (%)
Non-legume cover crop					
Mancan Buckwheat	45.3	17.7	6990	2.88	38.42
Shallow (Egyptain Wheat) Sorghum	80.7	26.9	4993	2.80	39.26
Dove Proso Millet	104.0	34.7	8597	3.22	38.77
Japanese Millet	91.0	30.3	6950	2.70	40.62
Piper Sudangrass	69.3	26.0	6197	2.80	40.14
GR-Hegari Sorghum	100.3	33.4	5637	2.45	34.75
Sugar Grazer II Sorghum-Sundangrass	54.7	18.2	6390	2.94	40.66
Wild Game Food Sorghum	73.0	24.3	5723	2.48	39.41
Dairy Master BMR Hybrid Grain Sorghum	72.5	16.1	6077	2.38	39.21
Tifleaf III Hybrid Pearl Millet	36.7	12.2	6737	2.38	39.22
Legume cover crop					
Sainfoin	60.7	20.2	6007	2.66	39.62
Catjang Cowpea	81.0	29.4	8150	3.11	39.96
Hairy Indigo	132.3	44.1	7473	3.05	39.87
Kester's Bobwhite Soybean	74.3	24.8	6343	2.93	40.26
Alyceclover	99.7	33.2	7327	2.98	39.48
Sunn Hemp	82.0	41.0	7483	3.61	40.66
Rongai Lab Lab	48.3	16.1	6030	3.20	40.17
Partridge Pea	88.3	29.5	7973	3.00	39.98
Hutcheson Soybeans	115.3	38.5	6793	2.70	39.95
Quail Haven Soybeans	48.3	16.1	5513	2.64	38.57
Prob > F	NS[b]	NS	NS	NS	NS

[a] Mean separation of treatments was analyzed using least significant difference (LSD) ($\alpha = 0.05$).
[b] NS = No significance.

Table 2. **Collard test crop total yield, average yield per plant, plant biomass, %N, and %C for each cover crop treatment.**

Treatment[a]	Total Yield (g)	Average Yield/ Plant (g)	Plant Biomass (g)	Nitrogen %	Carbon %
Non-legume					
Mancan Buckwheat	3386.7	564.4	1960.0	3.02	37.39
Shallow (Egyptain Wheat) Sorghum	3060.0	510.0	2073.3	3.30	37.27
Dove Proso Millet	2723.3	453.9	1786.7	2.95	37.36
Japanese Millet	2606.7	434.4	1140.0	2.85	37.37
Piper Sudangrass	2546.7	424.4	1425.7	2.93	38.63
GR-Hegari Sorghum	2540.0	423.3	1856.7	3.26	36.22
Sugar Grazer II Sorghum-Sundangrass	2506.7	417.8	1606.7	2.82	36.60
Wild Game Food Sorghum	2300.0	398.7	1726.7	2.69	37.16
Dairy Master BMR Hybrid Grain Sorghum	2100.0	369.4	1540.0	2.77	37.44
Tifleaf III Hybrid Pearl Millet	2046.7	341.1	1573.3	2.69	37.61
Legume					
Sainfoin	3420.0	570.0	1973.3	3.02	36.65
Catjang Cowpea	3220.0	562.4	1766.7	3.32	37.56
Hairy Indigo	3300.0	550.0	1870.0	3.24	37.23
Kester's Bobwhite Soybean	3110.0	518.3	1816.7	3.21	37.78
Alyceclover	3056.7	509.4	1630.0	2.94	37.67
Sunn Hemp	3033.3	505.6	2190.0	3.30	37.09
Rongai Lab Lab	2483.3	444.6	1740.0	2.60	37.28
Partridge Pea	2500.0	416.7	1513.3	2.96	37.71
Hutcheson Soybeans	2496.7	416.1	1470.0	2.87	37.05
Quail Haven Soybeans	2326.7	415.6	1370.0	2.99	37.98
Prob > F	NS[b]	NS	NS	NS	NS

[a] Mean separation of treatments was analyzed using least significant difference (LSD) ($\alpha = 0.05$).
[b] NS = No significance.

Table 3. Ranking system based on broccoli and collard yields to distinguish top overall cover crops.

Cover Crop	Legume/ Non-Legume	Collards Yield Ranking[a]	Broccoli Yield Ranking	Combined Ranking
Hairy Indigo	Legume	4	1	5
Catjang Cowpea	Legume	2	8	10
Sunn Hemp	Legume	8	2	10
Alyceclover	Legume	7	7	14
Dove Proso Millet	Non-Legume	5	5	14
Sainfoin	Legume	1	14	15
Japanese Millet	Non-Legume	12	3	15
Shallow (Egyptain Wheat) Sorghum	Non-Legume	6	10	16
Kester's Black and White Soybean	Legume	5	12	17
Mancan Buckwheat	Non-Legume	3	17	20
GR-Hegari Sorghum	Non-Legume	14	6	20
Hutcheson Soybeans	Legume	17	4	21
Piper Sudangrass	Non-Legume	13	11	24
Partridge Pea	Legume	16	9	25
Quail Haven Soybeans	Legume	12	16	28
Rongai Lab Lab	Legume	10	19	29
Sugar Grazer II Sorghum-Sundangrass	Non-Legume	15	15	30
Wild Game Food Sorghum	Non-Legume	18	13	31
Dairy Master BMR Hybrid Grain Sorghum	Non-Legume	19	18	37
Tifleaf III Hybrid Pearl Millet	Non-Legume	20	20	40

[a]1 = highest yield.

Awareness, use, and perceptions of biodiesel: A comparison of consumers in Belgium and the United States

Maggie Jo Pruitt, Leslie D. Edgar†, and Donald M. Johnson§*

ABSTRACT

Belgian (N = 61) and American (N = 134) fuel consumers were interviewed in the summer of 2012 to determine their awareness, use, and perceptions of biodiesel. Consumers who were aware of biodiesel were asked their perceptions. A significantly $P < 0.0001$) higher percentage of Belgian consumers (78.7%) reported owning or driving a diesel vehicle compared to American consumers (9.0%). Belgian and American consumers moderately agreed biodiesel is a high-quality fuel. For both Belgian and American consumers, there was no significant association between owning a diesel vehicle and being aware of biodiesel or having purchased biodiesel. Although Belgian and American consumers agreed that using non-food crops for biodiesel is justified, Belgians were significantly less supportive than American consumers of using food crops for biodiesel. Both Belgian and American consumers disagreed with the statement "I would never use biodiesel", and the two sets of consumers moderately disagreed that diesel engines would not run properly on biodiesel. Belgian and American consumers agreed that global warming is increasing; however, American consumers were more positive about the potential of biodiesel to reduce harmful exhaust emissions and global warming. Belgian consumers moderately agreed and American consumers agreed that biodiesel is better to use because it is made from renewable resources. Belgian and American consumers generally show similar perceptions of biodiesel, with the exception that American consumers were more positive toward the environmental and renewable aspects of biodiesel use. Recommendations for further research include gaining a better understanding of the potential positive influences that impact consumers' perceptions of biodiesel.

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I am from Bergman, Ark., majoring in Agricultural Education, Communication and Technology with a concentration in Communications. I am also minoring in Agricultural Business. During the spring, 2013 semester, I served as Director of Lectures on the Honors Student Advisory Board. I have served as a Bumpers College Student Ambassador, and am one of 25 nationwide college campus ambassadors for Agriculture Future of America. Currently, I am completing my Honors thesis project on the perception of genetically modified food in Belgium. Last summer, I interned with the Belgian Institute of Agricultural and Fisheries Research (ILVO) in Belgium and will intern with Scotland's Rural College (SRUC) in Edinburgh, Scotland, this summer. My goals are to attend graduate school and possibly enroll in a Ph.D. program, and my career goals are focused on international agricultural policy, trade, and sustainable development. This project was made possible through the guidance and assistance of my academic advisor, Associate Professor Leslie Edgar and by Professor Don Johnson.

INTRODUCTION

Biofuels are derived from non-fossil sources such as biomass, which is the organic matter of plants. Biofuels are required to meet no less than 80% of content volume of biological materials (Uhlenbrook, 2007). Ethanol and biodiesel are the two primary types of liquid biofuels, used in spark-ignition engines (ethanol) and compression-ignition engines (biodiesel). Ethanol is a product of sugar-producing or starch-producing crops by fermentation processes (Naik et al., 2010); biodiesel is currently made primarily by transesterification of vegetable oils, waste grease, or animal fats (Rojey and Monot, 2010). Biodiesel is one of the main alternative fuels traded internationally (REN21, 2012).

Worldwide biodiesel production increased from 17.8 billion liters in 2009 to 21.4 billion liters in 2012, a four-year increase of 20.2%. In 2011, the United States ranked first in biofuel (ethanol and biodiesel) production by country, with a total of 57.4 billion liters produced (REN21, 2012). Of the total, 3.2 billion liters were biodiesel (REN21, 2012). Belgium was the 11th highest biofuel-producing country, totaling 0.8 billion liters (0.4 billion liters of biodiesel; REN21, 2012).

Knowledge of current levels of greenhouse gas emissions and the prediction of a 50% increase in population on Earth by 2050 has reached consumers worldwide. Today, consumers are increasingly more aware of their purchasing behaviors with regard to the environment (Van de Velde et al., 2009). Biofuels give consumers an opportunity to purchase a transportation fuel that reduces harmful emissions to the environment; however, some consumers question other potential consequences of the use of biofuels. A 2006 survey determined that respondents with strong concerns about the environment felt that renewable fuels could potentially result in higher food costs (Skipper et al., 2009).

The primary purpose of this study was to determine and compare the awareness, use, and perceptions of biodiesel among retail fuel consumers in the U.S. and Belgium. The secondary purpose was to determine if there were significant relationships between awareness, use and perceptions of biodiesel and selected consumer demographic characteristics among American and Belgian fuel consumers.

MATERIALS AND METHODS

The guided interviews, for this study, were conducted at three retail fuel outlets in Northwest Arkansas and two retail fuel outlets in East Flanders, Belgium. In Northwest Arkansas, 134 interviews were gathered during five two-hour intervals during August and September, 2012. In Belgium, 61 surveys were collected in four one-hour periods in July and August, 2012.

Four interviewers, two in Northwest Arkansas and two in East Flanders, Belgium, conducted the interviews with a printed interview guide that was read to participants. The interview guide was developed by the researchers. A script was created to guide the interview, in which the interviewers stated their name, university affiliation, purpose of the study, and possible time duration for the interview, as well as a question to determine if the respondent was willing to be interviewed.

Interview questions were arranged in three sections. Part I consisted of three questions that required a "yes" or "no" response. These questions related to whether the participant drove or owned a diesel vehicle, if the participant had previously heard of biodiesel, and whether or not the participant had previously bought biodiesel or a biodiesel blend. The second part of the interview guide measured the participant's perceptions of biodiesel in a 13-question series measured on a 5-point Likert-type scale (1 = "strongly disagree" and 5 = "strongly agree"). Part III contained three questions to collect demographic information regarding the participant's age, gender, and miles driven per week. If a participant responded "no" to question two of Part I (awareness of biodiesel), the interviewer directly progressed to Part III. Respondents who answered "yes" to question two in Part I, previous awareness of biodiesel in the U.S. (n = 94) and Belgium (n = 50), completed Part II.

Five individuals with expertise in survey methodology (n = 2), biofuels research (n = 2), and biofuels marketing (n = 1) evaluated the interview guide and judged it to possess face and content validity. The instrument was administered twice to seven undergraduate students at a two-week interval with resulting coefficients (r) of stability of 1.0, 0.81, and 0.99, respectively. Four undergraduate students indicated no difficulty in understanding the directions or items during trial interviews.

Descriptive, correlational, and inferential statistics were used to meet the study objectives. The 0.05 level of significance was used for all statistical tests.

RESULTS AND DISCUSSION

This study sought to compare the awareness, use, and perceptions of biodiesel among consumers in the U.S. and Belgium. Of the 134 U.S. respondents, only 94 (70.7%) answered that they were aware of biodiesel prior to the interview (Table 1). In Belgium, 51 of 60 (83.3%) respondents were aware of biodiesel prior to the interview. The difference in awareness of biodiesel was not statistically significant (P = 0.06).

A significantly (P < 0.0001) higher percentage of Belgian consumers (78.7%) reported owning or driving a diesel vehicle compared to American consumers (9.0%; Table 1). Despite this greater use of diesel vehicles, Belgian (9.8%) consumers were no more likely than American (9.9%) consumers to have purchased biodiesel (P = 0.99).

For American consumers there was no significant association between owning a diesel vehicle and being aware of biodiesel (χ^2 = 2.80; P = 0.09) or having purchased biodiesel (χ^2 = 0.97; P = 0.33). Similarly, there was no significant association for Belgian consumers between owning a diesel vehicle and being aware of biodiesel (χ^2 = 0.02, P = 0.89) or having purchased biodiesel (χ^2 = 0.01; P = 0.93). This lack of association between owning or driving a diesel vehicle and awareness or (especially) purchase of biodiesel is both counter-intuitive and potentially troublesome for biodiesel producers and marketers.

Belgian (M = 3.54) and American (M = 3.57) consumers moderately agreed biodiesel is a high-quality fuel (Table 2). Both Belgian and American consumers slightly disagreed that biodiesel use results in increased engine repair and maintenance costs, with means of 2.78 and 2.82, respectively. American consumers (M = 2.27) moderately disagreed that biodiesel is available at most fueling locations in the surveyed area, as did Belgian consumers (M = 2.22) regarding fueling locations within the surveyed area of Belgium. Both Belgian and American consumers disagreed with the statement "I would never use biodiesel", with means of 2.06 and 2.12, respectively. American (M = 2.51) and Belgian (M = 2.46) consumers both moderately disagreed that diesel engines would not run properly on biodiesel.

Although Belgian and American consumers agreed that using non-food crops for biodiesel is justified, Belgians were significantly (P = < 0.0001) less supportive (M = 2.14) than American consumers (M = 2.98) of using food crops for biodiesel (Table 2). This is possibly related to the urbanization and decrease in agricultural land use in Flanders, Belgium, where the interviews were conducted (Tempels et al., 2012). Belgian consumers agreed (M = 4.30) that the European Union is too dependent on foreign oil sources; similarly, the American consumers agreed (M = 4.36) the U.S. is too dependent on foreign oil sources. American consumers slightly agreed (M = 3.28) that they would be willing to buy biodiesel even if it cost more than petroleum, while Belgian consumers remained neutral (M = 2.94).

Belgian (M = 4.02) and American consumers (M = 3.98) agreed that global warming is increasing (Table 2). However, American consumers were more positive about the potential of biodiesel to reduce harmful exhaust emissions and global warming. Belgian consumers (M = 3.52) moderately agreed and American consumers (M = 3.93) agreed that biodiesel is better to use because it is made from renewable resources. Although Belgian consumers agreed that the global temperature is rising, they have a tendancy to be less willing to pay more for biodiesel (M = 2.94). Belgian consumers' resistance to purchasing biodiesel does not support their view that the European Union is too dependent on foreign oil sources. These findings strongly support the need for educational efforts to increase biodiesel awareness and use and positively influence perceptions.

Among American consumers, age was the best predictor of attitudes toward biodiesel, with older respondents having less positive attitudes about the fuel quality, environmental, and food security aspects of biodiesel production and use (Table 3). American females were less likely than American males to support the use of food crops to produce biodiesel or agree that it is better to use biodiesel because it is made from renewable resources. However, age and gender were not particularly robust predictors of attitudes toward biodiesel, with the largest correlation (r = -0.37) explaining less than 14% of the variance in American consumers' attitudes.

For Belgian consumers, older consumers were less likely to agree that biodiesel was available at most fueling locations but were more likely to agree that biodiesel produced fewer harmful exhaust emissions (Table 3). Belgian female consumers were more likely to agree that using non-food crops to make biodiesel is justified. Again, neither age nor gender was a robust predictor attitudes toward biodiesel, with the largest correlation (r = -0.31) explaining less than 10% of the variance in Belgian consumers' attitudes.

Belgian and American consumers generally show similar perceptions of biodiesel, with the exception that American consumers were more positive toward the environmental and renewable aspects of biodiesel use. Recommendations for further research include gaining a better understanding of the potential positive influences that impact consumers' perceptions of biodiesel. Educational campaigns on the positive environmental effects of biodiesel would be beneficial. Research on the awareness of biodiesel should be expanded. Marketing expansion to include advertisement of biodiesel at fueling locations in Belgium and the U.S. may prove beneficial, in an effort to increase knowledge and awareness of specific locations to purchase biodiesel at fuel stations. Finally, efforts should be made to inform both American and Belgian consumers about the performance, environmental, and food security effects of biodiesel production and use.

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Table 1. American and Belgian consumers' vehicle type, awareness, and purchase of biodiesel.

	U.S.		Belgium			
Question	***n***	**Yes (%)**	***n***	**Yes (%)**	χ^2	***P***
Do you own or drive a diesel vehicle?	134	9.0	61	78.7	95.7	<0.0001
Had you ever previously heard of biodiesel before I mentioned it?	133	70.7	60	83.3	3.5	0.0615
Have you ever purchased biodiesel?[a]	91	9.9	50	9.8	0.0003	0.99

[a] Only respondents aware of biodiesel answered this question.

Table 2. Comparison of American and Belgian consumer perceptions of renewable and environmental aspects of biodiesel.

	U.S.		Belgium			
Statement	***M***[a]	***SD***	***M***[a]	***SD***	***t***	***P***
Biodiesel is a high-quality fuel (n = 94, n = 50)	3.57	0.78	3.54	0.50	0.32	0.75
Biodiesel use will increase engine repair or maintenance costs (n = 94, n = 50)	2.82	0.76	2.78	0.58	0.34	0.73
Using non-food crops for biodiesel is justified (n = 94, n = 50)	3.77	0.91	3.62	0.88	0.93	0.35
Using food crops for biodiesel is justified (n = 93, n = 50)	2.98	1.26	2.14	0.73	5.04	<0.0001
The average global temperature is increasing (n = 92, n = 50)	3.98	1.09	4.02	0.68	-0.43	0.67
Biodiesel is available at most fueling locations in my area (n = 94, n = 50)	2.27	0.82	2.22	0.98	0.30	0.76
The U.S. is too dependent on foreign oil sources/The E.U. is too dependent on foreign oil sources (n = 91, n = 50)	4.36	0.77	4.30	0.65	0.49	0.63
Biodiesel produces fewer harmful exhaust emissions than petroleum diesel (n = 94, n = 50)	3.53	0.86	3.06	0.79	3.21	0.0016
Diesel engines will not run properly on biodiesel (n = 86, n = 50)	2.51	0.86	2.46	0.73	0.35	0.72
It is better to use biodiesel because it is made from renewable resources (n = 91, n = 50)	3.93	0.83	3.52	0.73	2.95	0.0037
I would never use biodiesel (n = 93, n = 50)	2.12	1.02	2.06	0.79	0.35	0.73
I believe average global temperature is increasing (n = 92, n = 50)	3.96	1.09	4.02	0.68	-0.43	0.71
Increased use of biodiesel will reduce global warming (n = 93, n = 50)	3.34	0.90	3.02	0.80	2.13	0.03
I would be willing to buy biodiesel even if it cost more than petroleum diesel (n = 93, n = 50)	3.28	1.14	2.94	0.96	1.8	0.07

[a] Based on a 5-point Likert-type scale where 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; and 5 = strongly agree.

Table 3. Correlations between consumer perceptions and age and gender by country.

Statement	U.S.			Belgium		
	n	Age *(r)*	Gender[a] *(r)*	*n*	Age *(r)*	Gender[a] *(r)*
Own or drive a diesel vehicle[b]	134	-0.02	-0.07	61	0.05	0.06
Aware of biodiesel[b]	133	0.05	-0.14	60	-0.11	0.06
Purchased biodiesel[b]	91	0.05	0.08	50	-0.03	0.22
Biodiesel is a high-quality fuel[c]	92	-0.26*	-0.11	50	-0.13	0.23
Biodiesel use will increase engine repair or maintenance costs[c]	92	-0.05	0.14	50	0.05	0.18
Biodiesel is available at most fueling locations in my area[c]	92	0.08	0.07	50	-0.31*	-0.11
Using non-food crops for biodiesel is justified[c]	92	-0.02	0.03	50	0.27	0.29*
The U.S. is too dependent on foreign oil sources/The E.U. is too dependent on foreign oil sources[c]	89	0.04	-0.04	50	-0.01	0.05
Biodiesel produces fewer harmful exhaust emissions than petroleum diesel[c]	92	-0.37***	-0.08	50	0.29*	0.33*
Using food crops for biodiesel is justified[c]	91	-0.33**	-0.25*	50	-0.18	-0.05
Diesel engines will not run properly on biodiesel[c]	85	0.15	0.17	50	0.17	0.08
It is better to use biodiesel because it is made from renewable resources[c]	89	-0.21*	-0.24*	50	-0.17	0.20
I would never use biodiesel[c]	91	0.19	0.10	50	-0.04	-0.06
Increased use of biodiesel will reduce global warming[c]	91	-0.24*	-0.19	50	-0.06	-0.04
I believe average global temperature is increasing[c]	90	0.06	0.14	50	0.03	0.08
I would be willing to buy biodiesel even if it cost more per gallon than petroleum diesel[c]	91	-0.15	0.19	50	-0.08	0.09

[a] Gender coded as 1 = male and 2 = female.
[b] Coded as 0 = no and 1 = yes.
[c] Based on a scale where 1 = strongly disagree and 5 = strongly agree.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Characterization of seediness attributes of blackberry genotypes

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ABSTRACT

Fresh market blackberries can feel "seedy" when consumed. This "seediness" is associated with the presence of pyrenes which are comprised of a single seed enclosed in an endocarp. Small pyrene size (<3 mg) is preferred in both fresh-market and processed blackberry products. Yet, the proportion of pyrene weight to total berry weight can be more important than pyrene size. The objective of this study was to determine and compare descriptive sensory analysis and pyrene characteristics of blackberry genotypes from the University of Arkansas System Division of Agriculture blackberry breeding program. Panelists were trained according to Spectrum® methods and evaluated 20 genotypes for overall seediness. Pyrene characteristics, including weight and dimension, were measured for 22 genotypes. Seven of the 22 genotypes had an individual pyrene weight of 3 mg or less. Pyrene weight to berry weight ratio ranged from 2.7% ('Tupy') to 5.4% ('Prime-Ark® 45'). 'Tupy' had low individual pyrene weights and a low ratio, which are most likely factors that contribute to its widespread acceptance by consumers. Pyrene weight to berry weight ratio was positively correlated to descriptive overall seediness ($r = 0.70$) but not to number of pyrenes/berry. Therefore, finding a desirable pyrene weight to berry weight ratio is integral to decreasing perceived seediness in the development of new blackberry cultivars.

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MEET THE STUDENT-AUTHOR

Bethany Sebesta

Having spent most of my childhood in Northwest Arkansas, attending University of Arkansas was a natural choice. An instilled love for things that grow and a passion for learning brought me to the Horticulture Department in spring 2012. Being someone who seeks a challenge and has an innate desire to set myself apart, I asked for a Special Topics project even though it was not required. It was the best decision of my academic career. This experience enhanced my research and writing skills along with project development and critical thinking. In addition, I had the chance to compete in the Southern Region American Society for Horticultural Sciences, Gamma Sigma Delta, and the Ozark Food Processors Association student competitions; I placed in the first two for my poster and oral presentation.

During my university career, I have come to be a part of Alpha Lambda Delta, Gamma Sigma Delta, and Pi Alpha Xi. I have had the opportunity to use my horticultural knowledge in the community by serving at The Farm and Feed Fayetteville and on campus through the GroGreen club. After graduating this December, I plan to attend graduate school for plant breeding and genetics starting fall 2014.

The Undergraduate Research Scholarship given by Mrs. Mitchener, who funded the Mitchener Undergraduate Research Grant Program, helped make much of this study possible. Thank you to Drs. John Clark and Renee Threlfall for guiding me in project development and research techniques among other things. Thank you to Dr. Luke Howard for lending input and resources. In addition, it was a privilege to work interdepartmentally and learn from a department outside of my own. I am thankful for all of you who helped make this research project such a wonderful experience.

INTRODUCTION

Blackberries are grown throughout the United States and in other countries and used for both fresh market and processing. Blackberries are classified as a member of the *Rosaceae* family and *Rubus* genus (Finn and Clark, 2012). A blackberry fruit is an aggregate fruit comprised of many drupelets surrounding the receptacle or torus. The size of a blackberry fruit is determined by the combination of drupelet number and size (Clark et al., 2007). An individual drupelet includes a thin exocarp, a fleshy mesocarp and a hard, lignified endocarp, also known as a pyrene, which encloses a single seed (Tomlik-Wyremblewska et al., 2010).

Not until the late 1990s were fresh blackberries readily available in retail stores in the United States (Clark, 2005; Strik et al., 2007). Since then, blackberries have established a more prominent place in the market due to enhanced shipping capability, prolonged shelf life, and off-season availability (Clark, 2005; Strik et al., 2007). In 2005, worldwide blackberry area was 20,036 ha and was projected to increase by 2015 to over 27,000 ha (Strik et al., 2007).

The increase in acreage can be attributed in part to blackberry breeding programs. Blackberry breeding initiatives can be found on every continent with the exception of Antarctica (Strik et al., 2007). Blackberry breeding efforts have been in existence for over 100 years in the United States and continually work to enhance favored qualities and reduce undesirable ones. The first blackberry breeding program was initiated in 1909 at the Texas Agricultural Experiment Station (Clark and Finn, 2008). The oldest currently active program is at the U.S. Department of Agriculture–Agricultural Research Service at Corvallis, Ore. which began in 1928 (Clark and Finn, 2008; Finn and Clark 2012). In 1964, the University of Arkansas blackberry breeding program was initiated by Dr. James N. Moore (Clark, 1999). The University of Arkansas blackberry breeding program, based at the Fruit Research Station in Clarksville, Ark., has prioritized research efforts on attributes including thornlessness, erect growth habit, disease resistance, productivity, and adaptation (Clark, 1999; Clark and Finn, 2008). The fruit improvement objectives also included large fruit size, good flavor, firmness, and high fertility (Clark, 1999). The University of Arkansas breeding program also focuses on primocane-fruiting genotypes which produce fruit on first-year canes in addition to floricane-fruiting plants that produce fruit on second-year canes. Primocane-fruiting cultivars Prime-Jim®, Prime-Jan®, and Prime-Ark® 45 have been released (Clark and Finn, 2008). Even though breeding priorities may vary, most programs focus on promoting consumption through improved fruit quality (Finn and Clark, 2012).

Pyrene characteristics are distinctive to a blackberry genotype and can be classified into three groups: straight, concave, or convex (Wada et al., 2010; Wada and Reed, 2010). Variation in pyrene shape can occur in the same genotype and the outer layer of the endocarp typically has characteristic patterns of hollows (Tomlik-Wyremblewska et al., 2010). The structure, size, and number of pyrenes in the blackberry may influence mouth feel of the blackberries when consumed (Clark et al., 2007). Small seed size (<3 mg) is preferred in both fresh-market and processed blackberry products, and large seeds are objectionable (Moore et al., 1975). Fruit qualities such as seediness are important to consumers whether the berries are processed or consumed fresh (Clark and Finn, 2008). Large pyrene size, based on weight, length, or volume and seediness are also undesirable in processed blackberry products (Takeda, 1993). Yet, the proportion of pyrene weight to total berry weight is more important than pyrene size (Darrow and Sherwood, 1931). Pyrene weight and pyrene number were positively correlated with blackberry fruit weight (Moore et al., 1973).

Even though studies on blackberry pyrene characteristics and morphology on a limited number of cultivars have been published, there is little information on descriptive sensory analysis of fresh blackberries and the composition attributes that affect sensory scoring. The objective of this study was to investigate the descriptive sensory analysis and composition of blackberry genotypes from the University of Arkansas blackberry breeding program.

MATERIALS AND METHODS

Fruit. Blackberry fruits were hand-harvested from the Fruit Research Station, Clarksville, Ark. in 2012. 'Ouachita', 'Natchez', 'PrimeArk® 45', APF-190, A-2434, A-2312 ('Stella'), and APF-227 were harvested on 29 May; 'Ouachita', A-2108, 'Osage', A-2215, APF-156, APF-185, APF-205, and A-2473 were harvested on 7 June; 'Ouachita', A-2252, A-2316, A-2418, A-2416, A-2419, 'Navaho', and 'Apache' were harvested on 14 June. After morning harvest, the berries were transported in coolers to the Food Science Department, University of Arkansas, Fayetteville. In addition, blackberries were purchased commercially including 'Tupy' (Naturipe, Salinas, Calif.; fresh-market blackberries imported from central Mexico) and commercial frozen blackberries (Great Value, Wal-Mart Stores, Inc. Bentonville, Ark., cultivar unknown).

Sensory Descriptive Analysis. Descriptive sensory analysis of the fresh berries was performed at the Sensory and Consumer Research Center, Food Science Department, University of Arkansas, Fayetteville. Descriptive panelists (n = 8) participated in a 3 h orientation session where the descriptive ballot was developed through consensus. The commercial frozen blackberries were used as the reference sample. The fruit was evaluated on the same day that it was harvested. 'Apache' and A-2252 were not evaluated because of limited quantity. Due to scheduling conflicts with the panelists, only four descriptive panelists (n = 4) evaluated all the genotypes in the study.

Panelists evaluated the berries in duplicate using Spectrum® methods. Serving order was randomized across replication to prevent presentation order bias. The blackberry genotypes were served sequentially in 60-mL (2 oz) cups and were assigned random three-digit blinding codes. The blackberries were served at room temperature. Panelists were instructed to rinse their palettes with unsalted crackers and water between samples. Expectorant cups were provided. One paper ballot was completed per genotype for each replication. The descriptive panel scaled overall seediness of the berries on a 10-point scale (0 = no seeds to 9 = extremely seedy). The commercial frozen blackberries were thawed and used as a reference during each session and were scored a 7 for overall seediness.

Composition Analysis. All evaluations for composition of blackberries were done at the Grape and Wine Research Laboratory, Department of Food Science, University of Arkansas, Fayetteville. For each harvest date, samples were taken for descriptive sensory analysis. Three samples of approximately 100 g of berries were collected for each genotype, placed in plastic storage bags, and stored at -20 °C.

Berry and Pyrene Attributes. From the frozen berries, three berries per genotype and replication were used to determine attributes (individual berry weight, berry length, berry width, and drupelet number) and pyrene attributes (number/berry, dry weight/berry, and individual pyrene length, width, and height). The three-berry samples were weighed on a digital scale (Explorer, Ohause Corporation, Switzerland) and the width and height of each blackberry were measured with a certified calibrated digital caliper.

To determine pyrene attributes, 0.1 mL of Pec5L enzyme (Scott Laboratories, Petaluma, Calif.) was added to each bag containing the three-berry frozen sample to break down the skin and pulp. Once the berries thawed, they were hand-mashed in the bags. After 1.5 h at 21 °C, 100 mL of distilled water was added to each bag. The samples were then poured into a strainer. Under running water, the pulp was mashed against the strainer until only pyrenes remained. The pyrenes were placed onto paper towels and dried at ambient temperature (21 °C) for 1.5 h. The pyrenes for each three-berry sample were counted and weighed. The pyrenes were further dried in a laboratory oven (Fischer Scientific, Pittsburg, Pa., Isotemp®, Model 655F) at 55 °C (131 °F) for approximately 24 h. The pyrenes were removed from the oven and weighed, and then the length, width, and height of six randomly selected individual pyrenes per genotype and replication were measured with a digital caliper. Pyrene volume was calculated as length × width × thickness. The pyrenes for each genotype and replication were placed in plastic storage bags and stored in a freezer at -20 °C for further evaluations. Images of the individual pyrenes were taken, after freezing, using a camera with a macro lens attachment [Nikon D90, Tokyo, Japan; Nikon AF micro Nikkor 105 mm (1:2.8 D)].

Experimental Design. The experiment utilized a randomized complete block design with the 22 blackberry genotypes including the commercial sample, Tupy.

Statistical Analysis. Analyses were conducted using JMP® (V. 8.0; SAS Institute Inc., Cary, N.C.). Tukey's HSD (Honestly Significant Difference) was used for mean separation. Pearson's correlation was used to describe the relationship within and between descriptive intensity scores and composition.

RESULTS AND DISCUSSION

The descriptive sensory attributes and the composition of blackberry genotypes from the University of Arkansas Breeding Program indicated a range of measurement values.

Descriptive Sensory Analysis. Scores for overall seediness as rated by the panelists were not significantly different among the genotypes evaluated (data not shown). The average overall seediness ratings ranged from A-2418 with 7.25, 'Natchez' with 6.75, and 'Prime-Ark® 45' with 6.63 for the genotypes with the highest scores, and 'Tupy' with 4.38 and A-2416 with 4.38 the lowest. Selections APF-205, A-2312, and A-2215 all scored 4.75, the second-lowest value. Rating of overall seediness proved to be challenging for the panelists, as reflected in the lack of differences among the ratings even though there was a near 3-point range among the means. The lack of differences reflects substantial variation in the seediness ratings recorded by panelists.

Berry Attributes. The size and shape of the berries varied by genotype; some were long and narrow, and others short and wide. Average berry weight among genotypes varied from 5.1 g (A-2252) to 9.6 g (A-2434) (Table 1).

Pyrene Attributes. Pyrene attributes of each genotype were evaluated. 'Natchez' contained the greatest number of pyrenes having about 131/berry and 'Navaho' and 'Tupy' the least averaging 53/berry (Table 1). Number of pyrenes/berry for 'Natchez', A-2434, APF-156, and APF-205 were significantly higher than the averages for A-2108, A-2215, A-2252, A-2416, APF-185, APF-190, 'Apache', 'Navaho', 'Osage', 'Ouachita', and 'Tupy'. Genotypes having individual pyrene weight of 3.0 mg or less included: 'Tupy' (3.0 mg), APF-156 (3.0 mg), A-2416 (2.5 mg), APF-205 (2.6 mg), A-2252 (3.0 mg), A-2316 (2.9 mg) and A-2419 (2.7 mg); overall mean standard error for individual pyrene weight was 0.05. Genotypes A-2434, A-2108, and 'Apache' had individual pyrene weights of 4.0 mg or higher (data not shown). Average dry weight of pyrenes/berry varied from 160 mg ('Tupy') to 491 mg ('Natchez') (Table 1).

The proportion of pyrene weight per berry to total weight of berry is more important than pyrene size (Darrow and Sherwood, 1931). Of all genotypes, 'Prime-Ark® 45', 'Natchez', A-2473, A-2418, and A-2434 had high values for proportion of pyrene weight per berry to total berry weight; 'Tupy', A-2416, A-2215, and APF-190 had significantly lower values. The ratio for 'Prime-Ark® 45' and 'Natchez' was significantly higher than those for A-2215, A-2252, A-2416, A-2419, APF-185, APF-190, 'Navaho', and 'Tupy'. Even though some genotypes had a high proportion of pyrene weight to berry weight, these did not necessarily have the most pyrenes per berry. For example, the proportion of pyrene weight per berry to total berry weight for 'Apache' and APF-205 was 4.1%. However, the average number of pyrenes/berry for APF-205 was 122 pyrenes/berry and was significantly higher than that for 'Apache', which had 74 pyrenes/berry. This was especially notable for 'Prime-Ark® 45' which had 85 pyrenes per berry and a proportion of 5.4%. Conversely, A-2252, 'Navaho, and 'Tupy' had very low values for berry weight and average weight of pyrenes per berry. Pyrene volume ranged from 6.2 mm^3 (A-2416) to 10.7 mm^3 (A-2434) (Table 1).

The images of individual pyrenes from the genotypes evaluated were visually classified into three groups, straight, slightly concave, and convex (Fig. 1). Classification was based on the shape of the raphe, the lower edge of the pyrene. The following genotypes were classified as straight: A-2316, A-2418, 'Apache', APF-205, 'Osage', 'Ouachita', and 'Prime-Ark® 45'. Selections A-2416 and APF-156 were slightly concave. Genotypes A-2215, A-2312 (Stella), A-2419, A-2473, APF-185, and APF-190 were straight to slightly convex. Genotypes A-2108, A-2252, A-2434, APF-227, 'Natchez', 'Navaho', and 'Tupy' were convex. Blackberry pyrene shape and structure has been used previously to identify the genotype, based on the shape of the lower edge of the pyrene. Our results are in agreement with others. 'Navaho' and 'Tupy' were classified by others as convex (Wada et al., 2010). 'Natchez' was classified as straight to slightly convex and slightly convex to convex, 'Ouachita' as straight, and 'PrimeArk® 45' as straight to slightly convex (Bruce et al., 2012).

Correlations Within and Between Descriptive Sensory Analysis and Composition Attributes. Pearson's correlation was used to understand the relationship within and between descriptive intensity scores and composition attributes. For all genotypes, positive and negative correlations with significance were r = 0.98–0.70 ($P < 0.001$), r = 0.69–0.56 ($P < 0.01$), and r = 0.55–45.0 ($P < 0.05$).

Berry weight was positively correlated to berry volume (r = 0.93), number of pyrenes/berry (r = 0.70) and pyrene weight/berry (r = 0.78) (Table 2). Berry volume was positively correlated to pyrenes/berry (r = 0.58) and pyrene weight/berry (r = 0.67). Pyrenes/berry was positively correlated to pyrene weight/berry (r = 0.84) and pyrene weight/berry weight ratio (r = 0.63). Pyrene weight/berry was positively correlated to pyrene weight/berry weight ratio (r = 0.80). Descriptively-evaluated overall seediness was positively correlated to pyrene weight/berry (r = 0.51) and pyrene weight/berry weight ratio (r = 0.70).

CONCLUSIONS

Texture attributes, including seediness, are important to consumers and processors. Seven of the 22 genotypes had an individual pyrene weight of 3 mg or less and may be more accepted by consumers than those with higher pyrene weights. This may be a contributing factor to the widespread popularity of 'Tupy', which is grown in central Mexico but marketed in the United States from October until June. 'Prime-Ark® 45' had a high proportion of pyrene weight to berry weight and was scored among the highest for overall seediness. Conversely, 'Tupy' was among the lowest for both attributes. The positive correlation between pyrene weight to berry weight ratio and descriptive overall seediness supports Darrow and Sherwood's (1931) findings that can be useful for evaluating new developments in the Arkansas blackberry breeding program.

ACKNOWLEDGEMENTS

The completion of this project depended on others to whom I am most grateful. First, the Undergraduate Research Scholarship given by Mrs. Mitchener helped make much of this study possible. Thank you to John Sebesta for lending superior photography skills. Ensuring that things ran smoothly were Cindi Brownmiller for nutraceutical analysis and Sandra Sleezer for lab work, thank you.

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Table 1. Berry and pyrene attributes of blackberry genotypes.

Genotype	Berry weight (g)	Berry volume (mm^3)[†]	Pyrenes/ Berry	Pyrene weight (mg)/ berry	Pyrene weight/ berry weight (%)	Pyrene volume (mm^3)[‡]
A-2108	8.6 abcd [§]	4532 a	74 defghi	324 cdef	3.8 bcdef	8.7 abcde
A-2215	7.6 abcdef	3614 abc	67 fghi	226 fgh	3.0 ef	8.1 bcdefg
A-2252	5.1 f	2395 c	61 ghi	179 gh	3.6 cdef	7.7 bcdefg
A-2312	8.0 abcde	3474 abc	92 cdef	330 cde	4.2 abcdef	8.9 abcd
A-2316	6.2 cdef	3066 abc	88 cdef	257 defgh	4.1 abcdef	7.0 defg
A-2416	6.5 cdef	3168 abc	73 efghi	183 gh	2.8 f	6.2 g
A-2418	7.5 abcdef	3453 abc	91 cdef	356 bcd	4.8 abc	9.4 abc
A-2419	7.8 abcdef	4027 abc	99 bcd	271 defg	3.5 cdef	6.5 fg
A-2434	9.6 a	4457 ab	110 abc	452 ab	4.7 abcd	10.7 a
A-2473	6.9 abcdef	3306 abc	94 cde	317 cdef	4.6 abcd	7.6 cdefg
APF-156	8.8 abc	4310 ab	125 a	380 bc	4.3 abcde	7.7 bcdefg
APF-185	6.8 bcdef	3532 abc	70 efghi	245 efgh	3.6 cdef	8.7 abcde
APF-190	8.5 abcd	3788 abc	84 defg	276 defg	3.3 def	8.4 bcdef
APF-205	7.7 abcdef	3635 abc	122 ab	313 cdef	4.1 abcdef	6.7 efg
APF-227	7.0 abcdef	3352 abc	91 cdef	301 cdef	4.3 abcde	8.5 bcdef
Apache	7.2 abcdef	3944 abc	74 defghi	298 cdef	4.1 abcdef	9.7 ab
Natchez	9.4 ab	4253 ab	131 a	491 a	5.2 ab	8.9 abcd
Navaho	5.3 ef	2804 bc	53 i	179 gh	3.4 cdef	8.0 bcdefg
Osage	6.9 abcdef	3725 abc	73 efghi	273 defg	4.1 abcdef	8.4 bcdef
Ouachita	6.3 cdef	3155 abc	78 defgh	259 defgh	4.1 abcdef	7.2 defg
Prime-Ark® 45	5.8 def	2768 bc	85 cdefg	318 cdef	5.4 a	8.1 bcdefg
Tupy	6.0 def	2846 abc	53 hi	160 h	2.7 f	8.1 bcdefg

[†] Volume calculated as a cone.

[‡] Volume calculated as length x width x height.

[§] Means with different letter(s) for each attribute are significantly different ($P < 0.05$) using Tukey's honestly significant difference (HSD).

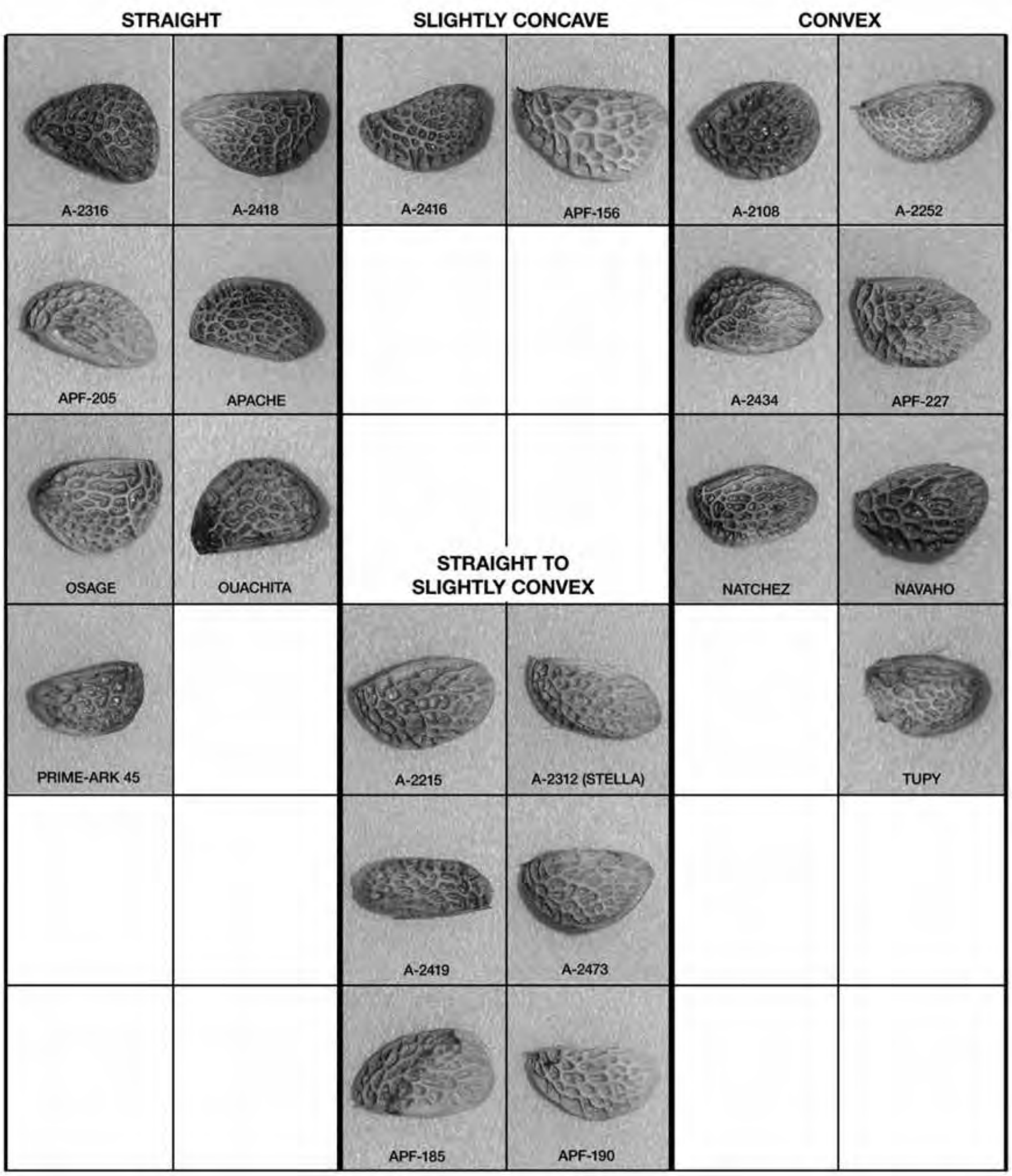

Fig. 1. Images of individual pyrenes from evaluated genotypes. Pyrene sizes in the images are not to scale relative to each other. Pyrenes were visually classified into the following four groups: straight, slightly concave, slightly convex, and convex, based on the shape of the raphe, the lower edge of the pyrene.

Table 2. Correlations between sensory descriptive analysis and composition attributes.

Attributes	Berry weight (g)	Berry volume (mm^3)	Pyrenes/ berry	Pyrene wt (mg)/ berry	Pyrene wt/ berry wt (%)	Overall seediness
Berry weight (g)	1.00					
Berry volume (mm^3)	0.93***†	1.00				
Pyrenes/berry	0.70***	0.58**	1.00			
Pyrene wt (mg)/berry	0.78***	0.67**	0.84***	1.00		
Pyrene wt/berry wt (%)	0.27	0.18	0.63**	0.80***	1.00	
Overall seediness	0.08	0.12	0.25	0.51*	0.70***	1.00

† Correlations with significance were r = 0.98–0.70 ($P < 0.001$), r = 0.69-0.56 ($P < 0.01$), and r = 0.50–45 ($P < 0.05$), respectively, ***, **, and *.

Textural and sensory qualities of muffins prepared with fermented rice bran

Breeanna S. Williams, Navam Hettiarachchy†, and Srinivas J. Rayaprolu§*

ABSTRACT

Rice is one of the most popular cereal grains in the world. Rice bran, a by-product of the rice milling process, contains an abundance of nutrients including protein, fiber, vitamin B complex, vitamin E, and other nutraceuticals. However, rice bran is underutilized in the food industry. In this project muffins were prepared with varying concentrations (2.5%, 5.0%, 7.5%, 10.0%, 15.0%, 20.0%, and 25.0%) of 60 mesh (250 μm) fermented rice bran (60 mFRB) and 80 mesh (180 μm) fermented rice bran (80 mFRB). A cappuccino muffin formulation was used as flavor for all the samples. The control sample was prepared without the fermented rice bran for comparison. Initial taste evaluations using student panelists demonstrated muffins incorporated with 80 mFRB were too dense, unacceptable, and discontinued for further study while the muffins prepared with 60 mFRB were found to be acceptable. The sensory qualities (texture, color, mouthfeel, aroma) and overall consumer acceptability of the muffins with 2.5%, 5.0%, 7.5%, and 10.0% 60 mFRB have lower firmness values in comparison to the control representing a softer texture. Three out of five sensory panelists considered muffins with 20.0% and 25.0% 60 mFRB to be acceptable in terms of color, texture, mouthfeel, and aroma. Hence, this project demonstrates that fermented rice bran products can be used in the preparation of breakfast food products like muffins. This innovative ingredient formulation concept can be useful in creating successful commercial bakery products that will provide protein, fiber and other nutrients.

* Breeanna Williams is a 2013 graduate of the University of Georgia with a major in Food Science and a minor in Nutrition Science. This paper is based on research conducted with the Department of Food Science at the University of Arkansas during her internship in 2012 funded through the Masterfoods USA, IFT Foundation.

† Navam Hettiarachchy is the faculty mentor and a University Professor in the Department of Food Science.

§ Srinivas J. Rayaprolu is a Program Technician and a Ph.D. candidate in the Department of Food Science.

MEET THE STUDENT-AUTHOR

Breeanna Williams

I am from Stone Mountain, Georgia. I attended Southwest DeKalb High School and graduated in the top 10% of my class in May, 2009. I am a senior at The University of Georgia majoring in Food Science with a minor in Nutrition Science. I am a recipient of both the Zell Miller Scholarship and the USDA Multicultural Scholars Program.

This year, I will serve as the Community Service Chair for both the Food Science Club and Minorities in Agriculture, Natural Resources, and Related Sciences. I was privileged to conduct this research at the University of Arkansas in Fayetteville through a 10-week food science research program funded by Masterfoods USA, IFT foundation. I would like to thank Dr. Navam Hettiarachchy for her guidance during this project and the opportunity to participate in this Summer Research Internship. We would like to thank Dr. Eswaranandam Satchithanandam for technical help and providing procedures for analysis.

INTRODUCTION

Rice is one of the most widely consumed cereal grains in the world and is grown in over 100 countries. It is also responsible for almost 25% of the world's food grain production (Wadsworth and Hui, 1992). Although rice is a staple food for two-thirds of the world population, the United States' per capita rice consumption is not large compared to world standards (Batres-Marquez et al., 2009). Because of the noted health benefits provided by rice and rice components, an increase in rice consumption may be helpful in improving the health of many Americans. A part of the rice grain, the aleurone layer that forms a major part of the rice bran contains a large amount of the nutritious components found in rice. A study by Kennedy and Luo (2012) states that rice consumption is associated with a lower BMI, smaller waist circumference and tricep skinfolds, and low serum insulin measures.

Rice bran can be identified as the brown, powdery material that is separated from rice during the milling of rough rice. It contains nutrients such as tocopherols, beta-glucan, and pectin and is composed of approximately 20% oil, 15% protein and 50% carbohydrate (Hernandez, 2000). In addition to such qualities, rice bran can be a food ingredient that contains protein that can be cleaved into active protein fragments called peptides. Researchers have found that the peptides from rice bran exhibit anti-obesity and anticancer properties (Kannan et al., 2009). The high quality protein generated peptides tend to reduce hypertension and oxidative stress, both of which are risk factors for cardiovascular diseases (Kannan et al., 2008).

The nutritional and functional properties of rice bran have contributed to the success of rice bran as an additive in baked goods such as cookies, crackers, pancakes, muffins, and breads (Barber et al., 1981). Although in recent years rice bran has been used in baked goods, not all products show improvements in sensory qualities and consumer acceptability when rice bran is incorporated. A decrease in cookie spread and bread volume has been observed while muffin volume increased (Sekhon et al., 1997). Even though there has been some research done investigating the effect of fermented cowpea flour addition on the rheological and baking properties of wheat flour, applications of fermented rice bran have not been utilized fully (Hallén et al., 2004). Co-/by-products like rice bran from rice processing when used as ingredients in the food products have excellent health benefits as well as an economical advantage.

Muffins are a popular breakfast item in the United States and are suitable products for incorporating rice bran to improve nutritional value with health benefits. Fermented rice bran is being utilized rather than rice bran that has not been fermented to possibly reduce the amount of leavening agents used during the baking process. An acceptable fermented rice bran muffin product is capable of increasing fiber and protein intake that may assist in creating a more balanced and healthier human diet. Hence, the objectives of this study were 1) to incorporate defatted and fermented rice bran at varying levels and prepare muffins and 2) to study the physiochemical properties and sensory characteristics of muffins made with rice bran.

MATERIALS AND METHODS

Materials. Heat stabilized de-fatted rice bran (HDRB) was obtained from Riceland foods (Stuggart, Ark.). All-purpose flour, unsalted butter, salt, sugar, baking powder, milk, cinnamon, vanilla extract, chocolate chips, instant coffee, eggs and canola cooking spray were purchased from local grocery stores. Xanthan gum was purchased from Danisco USA, Inc.

Preparation of Fermented Heat Stabilized De-fatted Rice Bran. Fermented HDRB was prepared by a patent pending and proprietary procedure by Hettiarachchy (2009). The post fermented rice bran is dried, ground, and sieved through 60 and 80 mesh sizes to prepare the 60 mesh (250 μm) fermented rice bran (60 mFRB) and 80 mesh (180 μm) fermented rice bran (80 mFRB).

Preparation of Muffins. The dry ingredients including all-purpose flour (64.3 g), sugar (41.4 g), baking powder (2.5 g), cinnamon (0.7 g), and salt (0.7 g) were homogenously mixed in a bowl using a metal whisk. In a separate bowl, instant coffee (2.8 g) was dissolved into milk (60.5 g) and added to the dry ingredients. To this mixture, melted butter (15.1 g), a beaten egg (13.9 g) and vanilla (1.1 g) and chocolate chips (11.7 g) were added. The muffin batter was poured into a greased mini-muffin tin tray until three-quarters full and baked at 185 °C for 17-20 minutes. To prepare the treatments, muffins were prepared by adding FRB at 2.5%, 5.0%, 7.5%, 10.0%, 15.0%, 20.0%, and 25.0% of the total weight of ingredients. The 20.0% and 25.0% rice bran muffins contain more milk, vanilla extract and xanthan gum, 90.8 g, 1.6 g, and 0.01 g, respectively. Muffins were cooled to ambient temperature before being evaluated for texture and color, and sensory analysis.

Physiochemical Properties of Muffins. The color of the muffin crumb was measured using a Minolta Chroma Meter (CR -300 Osaka, Japan) by calculating the L*, a*, and b* values. The L* value is the lightness variable, with values ranging from 100 (white) to 0 (black). The a* value measures the color of the sample, positive values being more red and negative values more green. The b* value also measures the color of the sample, positive values being more yellow and negative values more blue. Six samples were measured and the mean and standard deviation of the values were calculated.

Textural Properties of Muffins. Textural properties of muffins, firmness and springiness were determined using texture profile analysis with a TA-XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, N.Y.). The TA-XT2 Texture Analyzer was calibrated using a 5-kg weight. A 5-mm cylinder probe with a radius edge was used. The muffin sample was compressed at a constant rate of 1.0 mm/s to 25% of the original thickness. In this experiment, muffin firmness is defined as the force in grams, kilograms, or Newtons required to compress the muffin by 25%. To determine muffin springiness, the force after 30 seconds was recorded ($F_{30\ sec}$), then divided by the maximum force (F_{max}) and that quotient was then multiplied by 100% according to Eq. 1:

$$\left(\frac{F_{30\,sec}}{F_{max}}\right) \times 100 = \%\ \text{recovery} \qquad \text{Eq. 1}$$

A value closer to 100% indicates a more spring-like muffin.

Sensory Analysis. A group of five volunteer panelists evaluated color, texture, mouthfeel, and smell of muffins on a 5-point scale, with 5 being desirable for a trait. Muffins prepared for sensory analysis included chocolate chips.

Data Analysis. The values were analyzed using student's *t* test with a P value < 0.05. Color was measured six times to calculate its mean value and standard deviation. Firmness and springiness were measured three times to calculate its mean value and standard deviation.

RESULTS AND DISCUSSION

The color, firmness, springiness, and overall consumer acceptability of muffins prepared with fermented rice bran were analyzed in this study.

Evaluation of Textural Quality. Texture analysis calculations for firmness confirmed that all 80 mFRB treatments are firmer than the control and all 60 mesh muffin treatments except for the 60 mesh 25% (Table 1). Firmness of the control was determined by the texture analyzer to be 90.1 ± 10.5 g and the springiness was 41.3 ± 6.3%. Firmness in the muffin with 15% 80 mFRB was 243.5 ± 47.3 g and springiness was 28.1 ± 4.4%. During the textural analysis, it was also observed that the leavening agents used in the muffins, yeast and baking powder, created several air pockets in the crumb structure of both muffin treatments. The textural and color quality of the muffins was influenced by the air pockets formed. Xanthan gum was added to the 20% and 25% 60 mesh muffin treatments to achieve a more desirable texture considering the increase in amount of rice bran added.

The firmness of 60 mesh muffin treatments with less than 25% was lower than the firmness of all 80 mesh muffin treatments. The reason for this could be due to finer bran produced from 60 mFRB in comparison to

80 mFRB. A study by Chin et al. (2009) suggested that increased yeast level resulted in decreased bread density. This study also investigated the correlation between aeration and rheology of breads and suggests that there is a linear proportional relationship between bread density and bread firmness. This supports the findings of a less firm muffin with 60 mFRB compared to muffins with 80 mFRB. Hence, a lighter, fluffier crumb texture was found in the muffins in comparison to the control treatment (0% fermented HDRB).

As the percentage of 60 mFRB increased, muffin firmness also increased. Firmness of the muffins with no more than 20% 60 mFRB, although higher than the control, was lower when compared to firmness measurements for muffins with 80 mFRB. The springiness for most of the 60 mFRB muffin treatments is statistically similar to the control, while the springiness of 80 mFRB muffin treatments is lower than that of the control. Since springiness values closer to 100 represent a muffin that is most likely to be a spring (textural quality), it is evident that the fermented rice bran added to the muffins has an effect on the texture of the muffins.

Evaluation of Color. The color measurements were taken only for the 60 mFRB muffins while the 80 mFRB muffins were discontinued. The lightness variable, L* of several of the muffin treatments were higher than the control sample, although L* values of muffins with 10.0 and 20.0% 60 mFRB were similar to the control (Table 2). The a* value measures the color of the sample, where the positive values denote more redness while the negative values denote green. The a* value for the control (0 %) was 5.8 ± 0.2. All muffins with 60 mFRB have a* values that are statistically similar to the control. The b* value for the color of the sample denotes yellow to blue, where positive values are more yellow and negative values are more blue. The b* value for the control (0%) was 14.9 ± 0.4. All muffin treatments except for 20% 60 mFRB have a higher b* value than the control. There was no significant difference in a* values of the treatments compared to the control. However, there was a significant difference in b* values among the muffin treatments and the control (Table 2).

Analysis of Sensory Data. The most preferred muffin sample was the control which did not contain any HDRB. However, 2 of 5 panelists preferred muffin samples with 10% HDRB and 20% HDRB (Fig. 1). All the 5 panelists said they would recommend the product to family and friends. Four of the 5 panelists responded with confidence that they would be willing to purchase a similar product with HDRB in a commercial setting if reasonably priced. These results show that with further testing and adjustments to the formulation, it is possible to incorporate HDRB into a bakery product such as a muffin to provide protein, fiber, and other nutrients.

CONCLUSIONS

The results of this study show that incorporation of fermented rice bran in breakfast muffin formulations is a possibly feasible and applicable idea. Yeast fermented rice bran adds dietary fiber to the muffin which makes it a healthy breakfast that is sought by the health conscious consumers. The muffins prepared with 60 mFRB appealed sensory panelists and had some textural qualities similar to a regular muffin.

ACKNOWLEDGMENTS

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Table 1. Textural properties of muffins as measured by a texture analyzer.†

HDRB‡ Level %	Firmness (g)	Springiness %
Control (0)	90.1 ± 10.5d§	41.3 ± 6.3a
60 mesh 2.5	65.8 ± 9.9f	37.4 ± 1.4a
60 mesh 5.0	66.3 ± 1.8f	33.7 ± 2.9a
60 mesh 7.5	81.0 ± 8.8e	38.8 ± 4.0a
60 mesh 10.0	78.0 ± 7.3e	32.1 ± 2.6a
60 mesh 15.0	103.0 ± 7.2d	37.7 ± 2.3a
60 mesh 20.0	123.4 ± 62.0c	28.9 ± 14.3b
60 mesh 25.0	156.1 ± 38.9c	40.1 ± 3.0a
80 mesh 2.5	130.1 ± 17.9c	23.9 ± 3.6b
80 mesh 5.0	189.5 ± 33.4b	24.0 ± 1.1b
80 mesh 7.5	148.8 ± 14.0c	28.7 ± 2.7b
80 mesh 10.0	233.3 ± 27.6a	22.2 ± 2.8b
80 mesh 15.0	243.5 ± 47.3a	28.1 ± 4.4b

† Mean of three measurements ± standard deviation ($P < 0.05$).
‡ HDRB = heat stabilized de-fatted rice bran.
§ Values within a column represented with different letters are significantly different from each other.

Table 2. Color properties of muffins as measured by a chroma meter.†

HDRB‡ Level %	L*§	a*	b*
Control (0)	41.4 ± 0.7b¶	5.8 ± 0.2a	14.9 ± 0.4b
60 mesh 2.5	46.0 ± 0.6a	6.0 ± 0.1a	17.2 ± 0.8a
5.0	43.5 ± 5.7a	5.7 ± 0.2a	16.6 ± 0.5a
7.5	42.5 ± 0.2a	6.1 ± 0.1a	16.8 ± 0.3a
10.0	41.4 ± 1.4b	5.4 ± 0.2a	15.2 ± 0.8a
15.0	43.9 ± 0.7a	5.9 ± 0.2a	16.6 ± 0.4a
20.0	41.2 ± 0.8b	5.3 ± 0.3a	13.4 ± 0.6b
25.0	43.9 ± 0.7a	5.8 ± 0.3a	15.9 ± 1.5a

† Values are mean of six measurements ± standard deviation ($P < 0.05$).
‡ HDRB = heat stabilized de-fatted rice bran.
§ The L* value is the lightness variable, with values ranging from 100 (white) to 0 (black). The a* value measures the color of the sample, positive values being more red and negative values more green. The b* value also measures the color of the sample, positive values being more yellow and negative values more blue.
¶ Values within a column represented with different letters are significantly different from each other.

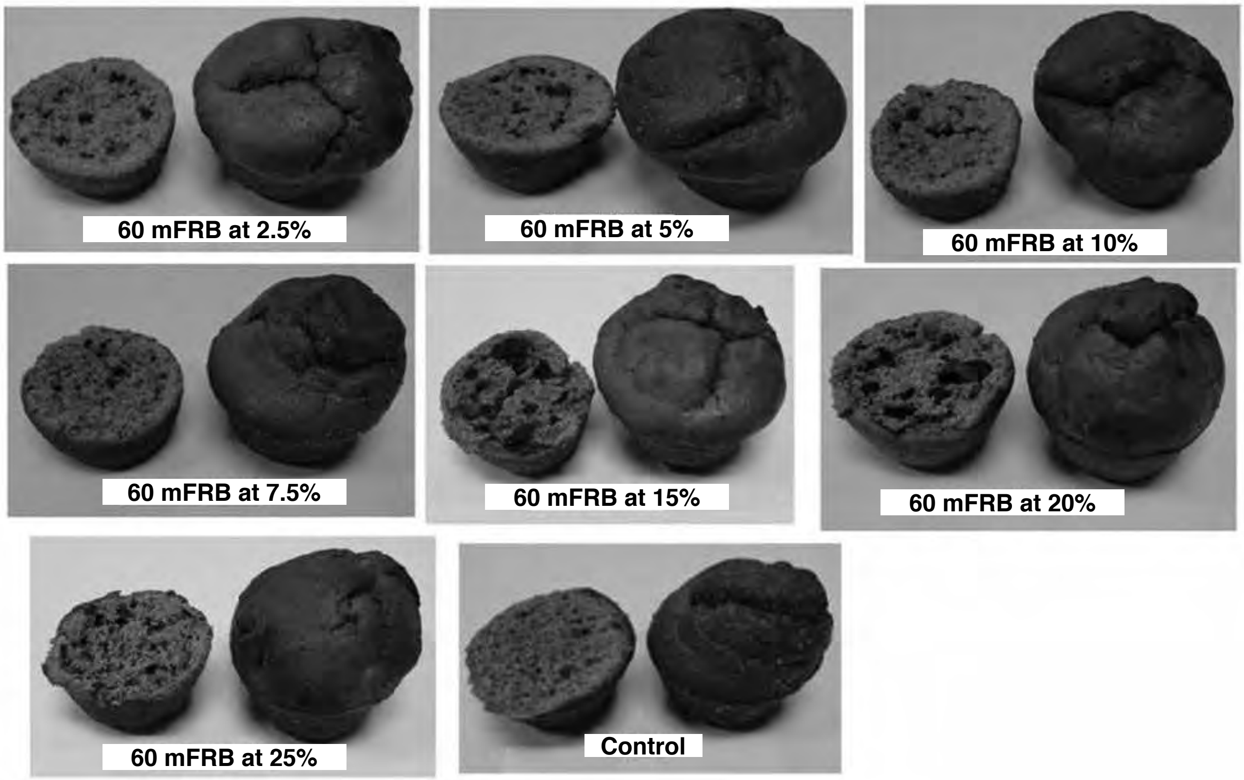

Fig. 1. Muffins prepared with 60 mesh fermented rice bran (mFRB) at varying concentrations and control sample; whole muffin and transverse section.

Interdisciplinary Creative Projects

This is the inaugural year for an exciting new addition to *DISCOVERY*: The "Interdisciplinary Creative Projects" section. This portion of the journal will be reserved for an assortment of papers, some authored by teams and others by individuals, that give a taste of the creative, interdisciplinary, hands-on interactive projects that are a part of many unique opportunities our students participate in throughout Bumpers College.

This year, we feature the work of students from the Leadership in Food Policy Special Topics Course.

Herbicide-Resistant Soybeans in Arkansas: Lessons Learned and Future Direction

Amy May West, Raven Anai Bough†, Hayley Jernigan§, Mike Norton‡, Katie Beth Thomas¶, Curt R. Rom#, and Michael E. Vayda††*

ABSTRACT

In Arkansas Delta soybean production, glyphosate resistant (GR) Palmer amaranth has significantly impacted weed management. The incidence of herbicide resistant (HR) weeds has far-reaching crop science, economic, and communications implications, which have been explored by the corresponding expertise of our research team members to form a comprehensive literature review. The review was used to develop policy recommendations to address current and future HR genetically modified (GM) crop use and the associated issues. The review of crop science research indicated an overall increase in herbicide application, as well as an increase in weed management programs focused around glyphosate rather than the application of multiple herbicides. The review also revealed some management methods have potential to resolve the problem, including alternating herbicide application, avoiding sub-lethal rates, using "burn down" herbicides prior to planting, crop rotation, tillage, and zero tolerance weed policies. The use of fewer herbicides rather than multiple types creates a monopolistic edge for the companies producing those few herbicides, allowing greater market control. Crisis communication methods, including developing internal readiness, conducting needs assessments, developing a relevant message, and conveying the message through appropriate channels, can be used to develop a response to the issue that will best communicate necessary information to the target audience. The team used these findings to formulate policy recommendations, which include management, economic, and communication plans that may provide a starting point to address the issue.

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‡ Mike Norton is a 2013 graduate with a double major in Agricultural Business and Poultry Science.
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# Curt R. Rom is a faculty mentor, the Director of the Dale Bumpers College of Agricultural, Food and Life Sciences Honors Program, and a professor in the Department of Horticulture.
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LEADERSHIP IN FOOD POLICY COURSE

Many students want to be change agents in our industry, with their goal being to economically and environmentally sustain the agriculture industry. The Leadership in Food Policy Course allows students the opportunity to get out of the classroom and put their desire for change to work. The 2012-2013 course focused on studying the impacts of glyphosate resistant palmer amaranth. Students spent the Fall semester listening to professionals from all aspects of the issue, from farmers affected by glyphosate-resistant Palmer amaranth to soil scientists. After obtaining a clear background, the class was able to break the issue into three sections: Agronomic, Economic, and Communication. Once broken up, the groups did their own research on the background of resistance rising in palmer amaranth in soybean fields in Arkansas. Once complete, the team used their literary research to make recommendations from political, managerial, and environmental standpoints. Finally, the team presented their findings to Stratton Seed Company, a seed-provider based in Stuttgart, Arkansas instigating talk of what is to come in Arkansas soybean production if resistance continues to impact production.

MEET THE STUDENT-AUTHOR TEAM

Amy May West

I am the daughter of Michael and Nancy West of Gravette, Arkansas, and a Junior majoring in Agriculture Business with a focus in economics. Active in student government, I was a member of Fresh H.O.G.S., Senator for the Dale Bumpers College, and will serve as the Chair of Senate for the 2013-2014 academic year. I have served as a College Ambassador for Dale Bumpers College, Vice-President of Ag Business Club, Jr. Panhellenic Delegate for Kappa Kappa Gamma Fraternity, Director of Awards for the Honors Student Board, and am a member of the AgriBusiness/Ag Econ Quiz Bowl Team. In order to gain agriculture-based experience in research, I work for Dr. H.L. Goodwin as a research assistant. After my freshman year, I studied abroad in Belize, working with farmers to enhance their business plans. Interested in Ag Policy, I interned in Washington, D.C. this summer for Senator Boozman and the National Rural Electric Coop in their Governmental Affairs Department. I intend to pursue a career in policy areas of agriculture.

Raven Anai Bough

I am a proud native of Fayetteville, Arkansas and graduated from Fayetteville High School in 2009. The following fall semester, I began studying Horticulture at the University of Arkansas. To gain supplemental skills and experience necessary for a career in research, I also pursued a minor in biology, worked as a lab-assistant for the Department of Horticulture, worked at a local plant nursery and retail center, and completed an internship funded by the National Science Foundation Research Experience for Undergraduates at the non-profit Donald Danforth Plant Science Center.

I plan to attend graduate school in California, the heart of United States fruit production, to pursue a career in horticultural plant breeding for crop improvement. Ultimately, I hope to attain a Ph.D. and manage my own laboratory and research programs in either a university or industry setting.

MEET THE STUDENT-AUTHOR TEAM

I am a newlywed from Ozark, Arkansas. I am a graduate of the University of Arkansas with a degree in Agricultural Education, Communication and Technology, as well as a minor in Agricultural Business. Upon completing my bachelor's degree, I began my graduate assistantship with the Agricultural and Extension Education Department. My research currently focuses on the Arkansas Cooperative Extension Service and the impacts of social media on agriculture. I would like to thank my mentor and graduate advisor, Dr. Leslie Edgar, for her help on this project. I would also like to thank Drs. Michael Vayda and Curt Rom, as well as Michele Helton for their guidance throughout the semester. This unique research opportunity allowed me to examine data from different aspects than my normal areas of focus. The collaboration of our classmates, mentors, and instructors was invaluable to the success of this project.

Hayley Jernigan

I am a graduate of the University of Arkansas with degrees in agricultural business and poultry science. I am a former Bumpers College Ambassador and former president of Collegiate Farm Bureau. I served as the 2012-2013 Chair of the Senate in the Associated Student Government and in that role directed the legislative and policy agenda for the student government. In my time at the University, I have studied abroad at the London School of Economics, received an Arkansas Department of Higher Education Student Undergraduate Research Fellowship to conduct research with Dr. Lanier Nalley, and completed an internship with the World Cocoa Foundation in Accra, Ghana. I am currently a summer intern at the White House and plan to work in Washington, D.C. for a few years prior to attending graduate school as a 2012 Harry S. Truman Scholar.

Mike Norton

I am a junior and the daughter of two Mobile, Alabama natives, William and Linor Thomas. In 2007, my family relocated to Quitman, Arkansas, where I graduated from Quitman High School in 2011. I came to the University of Arkansas the following fall to pursue both a B.S. in Agricultural Education, Communication and Technology and a B.A. in Drama. I hope to graduate in May of 2015 and continue on to seek a Master's degree in Agricultural and Extension Education. After earning my degrees, I intend to pursue a career in either publication or documentary filmmaking.

I am currently employed as a communications specialist with the Experiential Learning Lab, an organization based within the Agricultural and Extension Education Department that provides clients with various professional communications services. I also serve as the 2013 president of the University of Arkansas' chapter of Sigma Alpha, a professional agricultural sorority that is focused on scholarship, leadership, and service.

Katie Beth Thomas

INTRODUCTION

Today, the appearance of glyphosate-resistant (GR) weeds has greatly reduced the advantages of using the Roundup Ready genetically modified (RR GM) system. In Arkansas, over 94% of soybeans planted are RR GM crops (Scott and Smith, 2010). In the past few years, over 30 counties in Arkansas have reported GR *Amaranthus palmeri*, commonly known as Palmer amaranth, which is an exceedingly prolific weed whose properties include continuous germination, rapid vegetative growth, and production of high seed numbers (Scott and Smith, 2010). Because the composition of GM crops is similar to national percentages, Arkansas can act as a model state to examine the effects of GM technologies, especially herbicide-resistant (HR) RR crops.

Interviews with Delta farmers, local business owners, and experts that specialize in these areas were fundamental to the development of the main hypothesis of this comprehensive literature review, which states that RR GM soybean crops have an impact on GR Palmer amaranth in the Arkansas Delta. With soybeans comprising over 25% of Arkansas's farmland, this study focuses on the impacts of RR soybeans in Arkansas (FSA, 2012). Because of the controversial nature of GM technologies, this study focuses on synthesizing objective, scientific evidence to frame the issue. The study is broken into specialized areas including effects on crop management, the environment, social aspects, and economics. The appearance of GR Palmer amaranth emphasizes the influence of GM technology in Arkansas and will provide key answers for management recommendations involving current and future technologies.

AGRONOMIC TRENDS

The focus of soybean cultivar development has somewhat shifted since the introduction of GM crops in private versus public sectors due to rapid adoption of GM technology. Due to transgenic product protection under intellectual property laws, private breeders at larger companies perceive a greater value for investment in GM technology than conventional breeders and therefore focus on developing new GM traits (Miller-Garvin et al., 2010). Yet, large companies still rely on private breeders at small companies and public breeders for access to soybean germplasm for non-GM traits. Specifically, public breeders, such as those at the University of Arkansas, have increased breeding efforts for non-GM soy varieties with an emphasis on disease resistance, protein and oil contents, yields, and general germplasm enhancement (Miller-Garvin et al., 2010).

Herbicide-resistant GM crops have also shifted cropping practices. Larger farms have become more prevalent in Arkansas, and the number of farms greater than 2,000 acres has increased by 30% (Scott and Smith, 2010). Conservation tillage, where at least 30% of the soil surface is covered with crop residues after planting, has become widely adopted since weeds could be controlled after emergence with glyphosate (National Research Council, 2010). Genetically modified soy producers are also twice as likely to use conservation tillage or no-till practices than non-GM producers (National Research Council, 2010).

Before widespread adoption of HR GM crops, farmers utilized a variety of herbicides for weed control. It is estimated that HR soybeans have increased herbicide use by about 0.62 kg/ha per year (Benbrook, 2009). This trend may be attributed to the rising occurrence of GR weeds.

Widespread use of a single herbicide, glyphosate, has exacerbated the problem of HR weeds due to a large acreage of RR crops, making herbicide resistance a bigger problem than ever before. Generally, the more a herbicide is applied, the higher the proportion of HR phenotypes in a weed population that will arise due to increased selection intensity (Diggle and Neve, 2001).

In response to GR weeds as an effect of immense reliance on RR soybeans, agricultural companies are developing new GM cultivars with different herbicide resistance traits. Dicamba (Monsanto) and 2,4-D (Dow) resistant soybean crops are both undergoing development, with scientists stating that HR weeds will not be a problem with these GM crops (Mortensen et al., 2012).

TRENDS IN DIFFUSION AND DISSEMINATION OF COMMUNICATION

The Smith-Lever Act created the Cooperative Extension Service to assist in diffusing useful and pragmatic information (Rasmussen, 1989). Today, the Extension Service is diverse and widely distributed, offering the largest adult education system in the United States (Franz and Townson, 2008). "Having the ability to create, host, and facilitate access to educational materials and information over the Internet creates many new opportunities for Extension educators" (Rich et al., 2011).

Extending the reach of Extension is a need that must be met in the age of digital media and distance education. "People want their information delivered in smaller chunks. We've conducted focus groups who claim to still want fact sheets, but if you look at what they're actually using, it all relates to digital media and small bits of information," (K. Ballard, pers. comm.). "Berlo's SMCR (Sender; Message; Channel; Receiver) model is unidirectional and focuses on the source's attempts to manipulate the receiver's beliefs, attitudes, and behaviors" (Jandt, 1974). To understand the model, consider the Extension Service. They act as a media source that sends messages to farmers, the receivers. Feedback manifests in the form of altered practices.

Crisis communication management is crucial to the issue of GR Palmer amaranth (Edgar et al., 2012). When this occurs, "communication professionals must be prepared to manage the people involved with the crisis and reduce negative impacts," (Edgar et al., 2012). In the event of a crisis, one reliable spokesperson should be identified and provided with clear talking points that should address facts about the problem, how the problem will be addressed, and responses to foreseeable objections (L. Edgar, pers. comm.). Specific to the case of HR weeds, Extension should be considered.

ECONOMIC TRENDS

Since 1996, soybean farmers have seen positive changes in production resulting from GM seeds, with both increasing yields and decreasing production costs (National Research Council, 2010). However, after over a decade of RR technology in soybean production, the economic benefits of producing RR soybeans may be declining in areas such as yield and weed management efficiency (Nichols et al., 2008).

In 1997, RR soybeans only produced 13.1 bushels per hectare more than conventional fields (Fawcett, 1997). Yields have, as a trend, continually increased since 1980. Since 2004, yields have continued to increase but at a decreasing rate (USDA-NASS, 2011). There are three possible causes for this change: forces outside of management have affected yields; the current technology of RR soybean seeds is losing efficiency; or Palmer amaranth has reduced soybean yields. The answer may be found in a combination in all three of the above hypotheses (Mills, 2012).

An average GR Palmer amaranth infestation can cost farmers 27.2 bushels per hectare and farmers can spend close to $222 per hectare once the infestation becomes severe. Assuming these values, a GR Palmer amaranth infestation costs farmers $424.03 per hectare overall. This is the opportunity cost that farmers incur when producing RR soybeans (Klingman and Oliver, 1994). Minimal research has been conducted to determine how many Palmer amaranth plants per acre are considered an infestation, although the literature suggests that it does not take long for a pigweed infestation to go from being a small problem to a large problem (Ray, 2008).

Overdependence on a single mode of action can amplify an HR problem. Currently, the seed market uses a form of partial integration with contracts and licensing agreements by joining seed, chemical, and genomic roles into a singular company (Goldsmith and Sporleder, 1998). It appears that the trend will always exist towards vertical integration, yet this approach does not account for the costs associated with an increasing firm size (King, 2001; Chataway, 2001; Bijman, 2001a,b). Some biotechnology companies initially tried to incorporate an additional pharmaceutical role; however, most have divested that portion, illustrating that transaction costs act as a natural defense to complete vertical integration (King, 2001; Chataway, 2001; Bijman, 2001a,b).

Nevertheless, cohesion at some level between a firm and its suppliers or customers allows for better forecasting for both cost and revenue. By contracting with or directly owning plant breeders, genetics-based companies internalize the profits that would be lost without any vertical integration. Biotechnology development requires numerous processes. Integration enables access to cross-licensing and multiple patents, increasing the odds of completing research and development (R&D) and taking a product to market. Thus, there is an incentive for mergers and acquisitions, which leads to greater intellectual property rights for the larger post-merger organization.

If fewer pesticides are being used with the introduction of GM crops, firms producing these inputs have gained market power and leverage. But, given the availability of non-GM hybrid varieties that act as market competitors, the demand for seeds is still elastic as no one firm can exercise legitimate monopolistic power (Lin et al., 1995). Cooperatives, which were originally formed by farmers to combat supplier price opportunism within small or isolated markets, could provide increased seed genetics competition by investing directly in biotechnology research and development (Goldsmith, 2001).

RECOMMENDATIONS

Recommendations were analyzed using a cost-benefit analysis, both economically and environmentally, understanding that the primary weaknesses of Palmer amaranth are a shallow emergence depth, a short seed life and a high light requirement for germination. Using these few plant characteristics, producers can make economic and environmental decisions for their operation by listing costs associated with each recommendation, and then, based on the benefits and costs, make decisions related to financial and ecological management.

Best Management Practices

Pre-Planting. The first step to decrease the probability of HR weeds in HR soybeans is to begin with weed-free fields (Monsanto, 2012; Norsworthy et al., 2012; Smith et al., 2012). This is accomplished through a combination of methods, including tillage or a burn down with fire or herbicides (Norsworthy et al., 2012; Smith et al., 2012)

To further prevent the likelihood of HR weeds from arising or to diminish existing HR weed populations, it is crucial to establish a diverse herbicide program through multiple modes of action and application methods (e.g. foliar, soil, etc.) (Ervin et al., 2010; Norsworthy et al., 2012, Smith et al., 2012). It is also highly recommended to apply herbicides at full application rates to avoid sub-lethal rates that could result in selection for HR weeds that can survive those rates (Monsanto, 2012; Norsworthy et al., 2012; Smith et al., 2012).

Seasonal Non-Herbicide Weed Control. To acquire maximum HR and non-HR weed control, herbicide weed management programs should be supplemented with non-herbicide weed control methods, which often involve manipulation of weed biology. For prolific weeds such as Palmer amaranth, it is important to prevent weed seed production in order to reduce the weed seed bank (Ervin et al., 2010; Norsworthy et al., 2012; Smith et al., 2012). Employing the zero tolerance strategy significantly reduces the weed seed bank, and is accomplished through increased scouting and subsequent spot herbicide sprays as well as physical removal of the weed (Mortensen et al., 2012; Norsworthy, et al. 2012; Price et al., 2011).

Palmer amaranth seed is short-lived with an initial viability of 96% that decreases to 44-61% (shallow to deep burial, 1.25 cm and 40.64 cm, respectively) after a year, to 19-37% after two years, and to 9-22% after three years (Sosnokie et al., 2013). The Palmer amaranth seed bank and other short-lived, small seeded weeds can be further reduced by tillage (Norsworthy et al., 2012; Scott and Smith, 2010; Smith et al., 2012). Denser soybean rows can prevent light-activated germination of many weeds, including Palmer amaranth, by minimizing light penetration to the soil. This effect can be maximized by using early leafing soybean cultivars that are capable of forming a dense canopy before the germination of summer weed seeds occurs (Norsworthy, et al., 2012). Early planting also enables soybeans to become established and be more competitive against summer weeds (Mortensen et al., 2012; Norsworthy et al., 2012).

Long-Term Non-Herbicide Weed Control. Crop rotations, such as to rice or the Liberty Link HR soybean system in rotation with the RR HR soybean system, ensure a variety of herbicide modes of action between successive years (Norsworthy et al., 2012; Smith et al., 2012). Rotations including the Liberty Link HR soybean system provide ease of use similar to the RR HR system; whereas a rice-soybean rotation actually increases yields rather than continuous soybean cropping. In an 8-year study, soybeans grown after 1 or 2 years of rice had a 9.3 bu/acre yield increase with a $57.01 increased net return compared to continuous soybean cropping (Kurtz et al., 1993). Cover crops prevent winter weeds during their life cycle and (Norsworthy et al., 2012; Teasdale et al., 2007) may also provide additional profit as in the case of winter wheat. Though annual single soybean cropping has larger yields and lower production costs than double-cropping winter wheat after soybean, the double-cropping system provides a larger net profit over a year (LeMahieu and Brinkman, 1990). Based on more recent average five-year commodity prices, the double-cropping system had a net average profit of $255/ha; whereas single cropping had a net profit of $176/ha (Browning, 2011). Leftover winter wheat straw residues can be shredded via combine attachments or a rotary chopper after seed heads are harvested, enabling direct seeding of soybeans into residues (Minor and Wiebold, 1998).

Allelopathic plants are particularly useful as winter cover crops and summer residues, ultimately reducing herbicide input (Norsworthy et al., 2012). One study found a 94% emergence decrease of GR Palmer amaranth in cotton from the physical barrier and allelopathic effects of rye residue without tillage (Price et al., 2011). Other studies combining minimal tillage and rye residues cited 85% (DeVore et al., 2009) and 75% (Culpepper et al., 2011) decreases in emergence of Palmer amaranth. These three studies demonstrate the effectiveness of using cover crop residues in row cropping.

Field Border Weed Management. Weed management of HR soybean should also extend to surrounding vegetation and field borders (Norsworthy et al., 2012). Herbicide burn down or tillage maybe employed; however, repeat burn down applications would be necessary and tillage causes the soil to be more susceptible to erosion and invasive plant species (Buffin and Jewell, 2001). Establishing native grass stands is a more viable option, which will be less costly over the long term (Norsworthy et al., 2012). Other benefits of using switchgrass in a border stand are the creation of wildlife habitats, erosion control, flood management, and filtration of runoff from a soybean crop (Renz et al., 2009).

Soybean Breeding

Genetically modified breeders should not rely on stacking multiple HR genes to avoid increasing selection pressure for weeds expressing multiple herbicide resistance. Though the probability of multiple HR weeds occurring as a resulted of stacked HR genes is very low, immense soybean acreage, existing HR weeds, and past incorrect predictions for the appearance glyphosate-resistant weeds indicate that stacked HR GM crops will ultimately result in multiple HR weeds (Mortensen et al., 2012). Genetically modified and non-GM soybean breeding should develop soybean characteristics such as early maturation, faster maturation, dense canopy formation, and dense spacing tolerance. These characteristics would enable soybean cultivars to mature before weed flushes and limit soil light penetration, resulting in more competitive cultivars (Norsworthy et al., 2012). Faster turnover rates of GM cultivars, especially those that are HR, would be beneficial to producers by expanding growing options and enabling diversified crop rotations. Currently, it takes about 6-15 years for a new GM crop to be released commercially due to cultivar trials, evaluations, and the USDA approval process (Pocket K No. 17, 2012).

Cooperatives or completely public breeding programs (through Extension) could increase HR crop competition and help ensure crop rotation and multiple modes of action. Although some concerns lie with the property rights protection afforded to many biotechnology firms, decreasing patent protection may lead to more biologically excludable forms of trait development such as V-GURTS (variety genetic use restriction technologies, or self-terminating seeds), which would not reduce the HR issue since it focuses on patent protection, not on diversification between modes of action (Kvakkestad, 2009). Instead, property rights should only be lessened if they are coupled with increased public funding for breeding. Once developed, publicly developed traits could be transferred to the market through an auction system (Kvakkestad and Vatn, 2011).

Communications Management

A concise publication would be useful for farmers experiencing GR Palmer amaranth in their soybean fields. The North Central Soybean Research Program (http:www.ncsrp.com) offers publications, ranging in length from 2 to 16 pages, on managing similar issues such as white mold and sudden death syndrome. Currently, the University of Arkansas Extension's "MP44: Recommended Chemicals for Weed and Brush Control" and "MP197: Arkansas Soybean Handbook" are over 100 pages each, making quick reference difficult (Scott et al., 2012; SCC-UADA, 2012).

Policies

The emergence of GR weeds with high reproductive rates in Arkansas RR GM soybean fields, particularly Palmer amaranth, has resulted from a lack of education and infrastructure to ensure best management practices for HR crops. In order to preserve the short- and long-term effectiveness of current and future HR traits, it will be necessary to implement new policies and regulations. Such new regulations can be modeled after EPA mandated Insect Resistance Management (IRM) plans, which have been successful in preventing large scale insecticide resistance in insects to *Bacillus thuringiensis* (*Bt*) (EPA, 2012b). *Bacillus thuringiensis* corn and cotton are GM crops that express insecticidal proteins from a soil bacterium and were first released in 1996, followed by rapid adoption parallel to that of RR and other HR crops (Alexander, 2007).

Environmental Protection Agency regulations on *Bt* corn and cotton include the following components: 1) preliminary grower agreements, 2) required non-GM insect refuges, 3) grower compliance programs, and 4) resistance monitoring (EPA, 2012a). When purchasing GM *Bt* seed, farmers must sign a contract agreement that EPA regulations will be followed. Educational materials or workshops must also be supplied by the seed company (Weiss, 2000). For any *Bt* corn hybrids, farmers are required to maintain at least 20% of their total corn acreage as non-*Bt* corn for insect refuge (Cullen et al., 2008). The use of *Bt* cotton requires at least 50% of total acreage to be non-*Bt* (EPA, 2012a). Non-*Bt* refuge areas decreases the probability of mating between solely *Bt*-resistant insects, ensuring that *Bt* susceptibility is retained in populations (Cullen et al., 2008). There are several field configurations possible for both *Bt* corn and cotton, though a refuge area must be within 0.80 km of the *Bt* planting (Cullen et al., 2008).

Seed companies that are registered to sell *Bt* seed are required to establish a grower compliance program to identify and address noncompliance that includes field and planting record inspections through the EPA (Cullen et al., 2008). Methods used by seed companies to ensure compliance are anonymous phone surveys, on-farm visits, and complaint programs through phone or digital means (Cullen et al., 2008). Farmers that do not comply with the IRM refuge are initially given a warning from the seed company and required to have a compliance assessment the second year. If the farmer fails to meet compliance the second year, they are denied access to *Bt* seed the third year. Repeated noncompliance results in revoking the right of a farmer to grow *Bt* seed.

In the case of *Bt* corn, 32% of farmers indicated they would not plant a refuge if it were not required, 37% were undecided, and only 30% stated they would plant a refuge regardless of regulation (Alexander, 2007). This perception indicates that best management practices may not be followed by a significant number of farmers without regulation. Regulations similar to the EPA mandated IRM program would be beneficial to a sustainable use of HR cropping systems by requiring good stewardship.

With IRM as a model, a herbicide resistance management program should first require a license or contract that includes an education component for HR crop best management practices in the form of an examination, training, or a workshop. Literature should also be provided to each HR crop grower for best management of HR crops. Growers should be required to maintain a proportion of their field as non-HR to ensure the existence of herbicide susceptible weeds that can decrease HR populations. Additionally, a diverse herbicide program should be required that includes different methods of application, modes of action, and crop rotation. Refuges and diversified herbicide programs can be enforced by the submission of plans along with a license or contract and by assessments, surveys, and anonymous phone tip-lines similar to the IRM program. Non-compliance should be initially penalized by a warning, followed by probation, and ultimately revocation of the privilege to plant HR seed if non-compliance continues. Herbicide-resistant weed monitoring should also be implemented.

For highly prolific weeds, such as HR Palmer amaranth, it may be necessary to implement a zero tolerance law with fines for non-compliance. Oklahoma's Noxious Weed Law and Rules regarding Canada, musk, and Scotch thistle eradication can be used as a model (ODAFF, 2000). This law requires landowner control to prevent the mentioned thistle species from going to seed, with fines being bestowed for up to $1000 per day for each violation. Violations are investigated based on complaints that can be submitted anonymously to the Oklahoma Department of Agriculture, Food, and Forestry.

CONCLUSIONS

In Arkansas Delta soybean production, GR Palmer amaranth has significantly impacted weed management. This incidence of HR weeds has far-reaching crop science, economic, and communications implications, which have been reviewed by the corresponding expertise of our research team members. The team has used findings to formulate recommendations that address agricultural management, economics, and communications and provide a starting point to address the issue. The appearance of GR Palmer amaranth emphasizes the influence of GM technology in Arkansas and provides implications for establishing economical best management practices, enhancing communications, and developing policies that will ensure short- and long-term viability of current and future GM technologies.

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